Industrial QUALITY CONTROL

VOL. VI JULY, 1949 NO. 1

See J. W. McNairy "An Appraisal of Quality Control," pp. 5-14

AMERICAN SOCIETY FOR QUALITY CONTROL

Johansson

BROWN & SHARPE

BS

Johansson Gage Blocks

now available through

Brown & Sharpe Distributors

NEW CATALOG

Send for a copy of the latest catalog on all Johansson Gage Blocks and Accessories . . . now made by Brown & Sharpe. This catalog contains illustrations and detailed information on the use and specifications of these world-famous standards.

These famous precision standards of industry are conveniently accessible through Brown & Sharpe Distributors. Thus, industry is assured a continuing dependable source of supply for JO-BLOCKS and Accessories.

With the purchase of the Johansson Division from Ford Motor Company, Brown & Sharpe acquired all rights to manufacture and distribute Johansson Gage Blocks and Accessories throughout the Western Hemisphere. Since that time, it has obtained the rights to world-wide distribution.

The Brown & Sharpe name is industry's guarantee that the traditional precision of these Johansson products will be maintained without compromise. Brown & Sharpe has symbolized leadership in the development and manufacture of precision measuring devices, machines and tools for more than 100 years. Brown & Sharpe Mfg. Co., Providence 1, R. I., U. S. A.

We urge buying through the Distributor

BROWN & SHARPE

Industrial Quality Control

VOL. VI **JULY, 1949** **No. 1**

Table of Contents

Page

Basic Conference Series on SQC 3
All-Day Meeting on Quality Control 3
An Appraisal of Quality Control
J. W. McNairy 5
Use of Control Chart Techniques in Maknig a Quality Audit—Part I
Bonnie B. Small 15
Practical Aids Department, Ellis R. Ott, Editor 20
Aids for Computing Limits for p Charts
John M. Howell
Probability Center Lines for Standard Deviation and Range Charts
Churchill Eisenhart 24
Checking Process Spread Against Specification Limits for a Process Operating in Tight Control
Edward S. Smith 26
Guest Editorial, ASQC Dues
George D. Edwards 29
American Society News
Annual Meeting—1949 30
Membership on the Board of Directors 30
Membership on the Executive Committee 30
More Stringent Qualifications for Senior Membership . . . 30
ASQC Convention — 1950 30
Examining Committee 30
Shewhart Medal Committee 31
Classified Advertisements
Positions Wanted 31
Consulting Services 31
Advance Notice — Fourth Midwest Conference 31

BASIC CONFERENCE SERIES ON STATISTICAL QUALITY CONTROL

Rutgers University will offer its Second Basic Conference Series on ten consecutive Tuesday afternoons and evenings, beginning October 4 and concluding December 6, 1949. This Series will present the basic techniques of modern quality control applied to practical problems of production.

There will be two types of program each day:

A. Afternoon session — 2:15 to 5:15 p. m. These afternoon meetings are designed to provide a general understanding of a quality control program, including applications of control charts to process control and the advantages and methods of scientific sampling plans in an inspection program. Practical applications of the modern techniques will be stressed with lectures, class instructions, and group discussions. Emphasis will be on the applications of the techniques and not on the underlying theory. Short case histories of actual plant experience will be given by industry representatives. Instruction will be provided by Paul C. Clifford, Montclair State Teachers College and Ellis R. Ott, Chairman, Mathematics Department of University College, Rutgers University.

B. Dinner Session — 6:00 to 9:00 p. m. Nationally prominent leaders in statistical quality control are being scheduled to talk to the group on different aspects of quality control in which they are especially interested. These evening talks by different men from industry will be integrated with the afternoon programs.

The fee for the ten meetings will be $100 per registrant. This includes reference material and texts but does not include dinner. Further inquiries should be addressed to Dr. Ellis R. Ott, Rutgers University, 77 Hamilton Street, New Brunswick, N. J.

ALL-DAY MEETING ON QUALITY CONTROL

An all-day meeting on the practical applications of quality control to the problems of production will be held on the Men's Campus of Rutgers University, on Saturday, September 17.

The program will emphasize case histories presented by men from different chemical, electrical, and mechanical industries in New Jersey. There will be a special session for instruction in the basic techniques of quality control, including demonstrations to compare the advantages of scientific acceptance sampling plans with ordinary inspection practices. There will be another session to present plant experiences applying quality control methods to reduce costs, rejects, and rework, and insure an economic balance between cost and quality. Following luncheon in the Rutgers University Commons, there will be a combined meeting to hear an invited talk on quality control by a nationally prominent representative of industry.

The general chairman of the meeting is E. H. MacNiece, Director of Quality Control, Johnson - Johnson. Chairman of the committee on general arrangements is Ellis R. Ott.

INDUSTRIAL QUALITY CONTROL

Published Bi-monthly
by the

AMERICAN SOCIETY FOR QUALITY CONTROL Inc.

22 East 40th Street,
New York 16, N. Y.

Ralph E. Wareham, President
122 Orchard Ridge
Chappaqua, N. Y.

Wade R. Weaver, Vice-President
Republic Steel Corporation
Cleveland, Ohio

Simon Collier, Executive Secretary
Johns-Manville Corporation
New York, N. Y.

Alfred L. Davis, Treasurer
Rochester Institute of Technology
Rochester, N. Y.

Advisory Council

Dr. E. U. Condon
Director, Bureau of Standards,
United States Department of Commerce
Washington, D. C.

Mr. M. Herbert Eisenhart
President, Bausch & Lomb Optical Co.
Rochester, New York

Brig. Gen. Hermon F. Safford
Executive Vice-Pres.,
Ohio Rubber Co.
Willoughby, Ohio

Dr. Walter A. Shewhart
Member, Technical Staff
Bell Telephone Laboratories, Inc.
Murray Hill, New Jersey

Mr. Charles D. Wiman
President, Deere & Co.
Chicago, Illinois

Editorial Board

Mason E. Wescott, Chairman
Martin A. Brumbaugh
Irving W. Burr
Cecil C. Craig
Harold F. Dodge
Churchill Eisenhart
Joseph M. Juran
Lloyd A. Knowler
Frederick Mosteller
Edwin G. Olds
Ellis R. Ott
William B. Rice
Leslie E. Simon
A. E. R. Westman

E. H. Robinson, Editor
IQC NEWS SUPPLEMENT

* * *

Copyright 1949
by the
AMERICAN SOCIETY FOR QUALITY CONTROL
Inc.

Printed in U.S.A.
All rights reserved

Neither this magazine nor any portion thereof may be copied or otherwise reproduced without written permission of the copyright owner.

Permission for reproduction of certain specific portions of the contents may be given upon request, with the understanding that due source credit will be accorded.

Statements and opinions given in articles and papers appearing in INDUSTRIAL QUALITY CONTROL are the expressions of contributors for which the Society assumes no responsibility.

Correspondence is invited on all controversial matters.

General Information

INDUSTRIAL QUALITY CONTROL is published in January, March, May, July, September, and November, and is mailed to all members of the Society as one of the privileges of membership.

Direct Subscriptions to INDUSTRIAL QUALITY CONTROL will not be accepted from individuals. However, subscriptions to the magazine will be received from Libraries and like institutions at five dollars per year. Remittances must be in United States funds and should be sent directly to the Treasurer of the Society.

Membership in the American Society for Quality Control is available in three grades through local Sections or directly through the Executive Secretary. Annual dues for direct national membership are: for Members, $5.00; for Senior Members, $10.00; for Fellows, $15.00. The Member grade is open to any person of good character who is 21 years of age and engaged or interested in quality control. Information covering higher grades of membership and concerning local Sections may be obtained from the Executive Secretary.

Membership in the Society is personal and professional, and is not open to corporations, companies, or other organizations.

Contributions to the Society for the support of its activities will be accepted from corporations, companies, and others.

Advertising space in INDUSTRIAL QUALITY CONTROL is available.

Correspondence concerning membership, dues, and allied matters should be addressed to

Simon Collier,
Executive Secretary, ASQC
22 East 40th Street
New York 16, N. Y.

Correspondence concerning institutional subscriptions, other financial matters, and requests for back issues should be addressed to

Alfred L. Davis, Treasurer ASQC
Rochester Institute of Technology
Rochester 8, N. Y.

Make checks payable to:
American Society for Quality Control.

Inquiries regarding advertising rates, advertising contracts, and advertising space available should be addressed to

Raymond S. Saddoris
A. O. Smith Corporation
Milwaukee 1, Wis.

Editorial correspondence and requests for copyright releases should be addressed to

Mason E. Wescott
Chairman, Editorial Board
Lunt Hall, Northwestern University
Evanston, Illinois

Correspondence concerning news items and other matters appropriate for IQC NEWS SUPPLEMENT should be addressed to

E. H. Robinson
Johnson & Johnson
4949 West 65th Street
Chicago 38, Ill.

Cost of Back Issues

Back issues, comprising Volumes I through V are available at $8.00 per volume, including the Index. Individual issues at $1.50 each.

An Appraisal of Quality Control*

J. W. McNAIRY

MANAGER OF ENGINEERING AND MANUFACTURING, APPLIANCE AND MERCHANDISE DEPARTMENT, GENERAL ELECTRIC COMPANY, BRIDGEPORT, CONNECTICUT

INTRODUCTION

It was with considerable pleasure that I accepted an invitation to speak on the matter of Quality Control. It should be understood, however, that I am only able to present some observations and comments, based largely on our experiences and observations, on the operation of an engineering and manufacturing organization devoted entirely to the production of electrical household appliances. I am not authorized to speak for industry generally on this subject, but I am of the opinion that, in most instances at least, our observations and experiences have much in common with others. I shall confine my remarks to an appraisal of Quality Control from the viewpoint of one whose responsibility is the business of engineering and manufacturing salable electrical devices, particularly for the home.

Most of the basic practices of Quality Control, with the possible exception of some of the new statistical techniques, have been used for many years. There has always been considerable emphasis on quality and the control of it during manufacture by reputable manufacturers. The goal of all successful manufacturers is to maximize value in the equation:

$$\text{VALUE} = \text{QUALITY}/\text{PRICE},$$

an excellent theme for such a talk as this.

But, considering a presentation, such as this, we naturally look for something new to talk about and, from the particular viewpoint I have indicated, I think the most significant trend recently is the greater recognition by industry of the importance of controlling quality through a systematic, separately identified, well-manned organization, concentrating on this problem. It is my belief that this is coming about because of a better realization that the quality contained in our products can be improved concurrent with reduced costs — both profitable accomplishments.

* Paper presented to Metropolitan Section, ASQC, New York City, November 16, 1948.

We can hardly claim that even this is radically new, because integrated, separately-identified Quality Control installations have already been made in a number of industries, excellent examples of which are those in the Bell Telephone Laboratories, Western Electric, Westinghouse, Sylvania, SKF, and others. These organizations have pioneered the way and have set a splendid example which we have found helpful and which, I suspect, has been helpful to many others. Perhaps the only claim to newness should take the form of a broader recognition and appreciation, and a wider utilization than ever before.

In our organization we have concentrated on improvement in quality, with some identification, for many years past. This identification, however, has not been under the title of Quality Control, but rather has been part of factory contact engineering or perhaps as a part of a rather elaborate, more or less conventional inspection organization. As such, it could not be and was not termed Quality Control engineering.

Today in our company we do have an increasing interest and a better understanding of the need for the best Quality Control organization and practices. The value such a function can have in engineering and manufacturing products such as ours is becoming more apparent every day. I think there is a tendency often to associate the idea of Quality Control with large and complicated products, particularly those demanding high accuracy. Similarly, I think that often extreme accuracy is considered to be evidence of adequate quality. While I believe high accuracy to be an important consideration in the matter of quality, nevertheless it is by no means the sole consideration. I find a tendency in many shops to base claims for high quality on parts which are made to very close tolerances and on extremely accurate machining equipment, gages, etc. In many of these cases, I have actually discovered that the quality level is determined by other considerations, such as dirt, foreign materials in assemblies, and perhaps failure to do a number of operations adequately—particularly in assemblies—by properly tightening bolts, screws, gaskets, etc. In many instances, therefore, it may be more important to hold the bending or forming of a lever or some other part to $\pm 1/16''$ than to control the shaft, or similar part, to $\pm 0.010''$.

With this viewpoint in mind, I have selected for this discussion some examples of simple, ordinary parts in an attempt to illustrate that the opportunities for Quality Control on rather simple products, made up of simple parts, are just as great, and perhaps greater than in the field of extremely complicated, highly accurately made products, particularly in high volume lines.

I am qualified to speak only as a member of the Appliance & Merchandise Department of the General Electric Company, and almost everything I say is based on this department's problems. However, let me stress, at the outset, that I consider many of the principles I shall enumerate later to have general application. In General Electric, Quality Control is a coordinated company-wide activity with all departments of the company developing programs along similar lines, but with modifications to fit their particular circumstances.

QUALITY CONTROL IN THE HOUSEHOLD APPLIANCE FIELD

We, in the Appliance & Merchandise Department, in common with other manufacturers of electrical household appliances, think we have perhaps the most acute need for quality in our products. We see an ever increasing number of our products, intended for use in the home, stream out of our plants in ever increasing volume. As our consumer uses these appliances, we believe his reaction to their quality, from his

daily contacts, shapes his judgment of the whole company. We are pretty sure that on the average he probably knows little about the quality of the heavy apparatus, such as turbines or substation transformers, which our company builds, because he has no direct contact with them. We believe that most of his impressions result from his constant contact with our department's products on which he gets impressions every day. This involves such things as the coffee maker, the range, the dishwasher, the vacuum cleaner, the refrigerator, etc., throughout the day and now, with the electric blanket, throughout the night. Thus, he constantly puts our manufacturing integrity and our engineering ability to test.

Moreover, a few single irritations or failures of one or two appliances can more than offset numerous satisfactory experiences. Usually, troubleless operation is accepted as a matter of course. I am told, by my Quality Control associates, that we must guard against the "mavericks."

When we multiply the number of our products by the number of users and consider the number of times they make use of some one of our products, the number of these exposures more than ever convinces us that we must avail ourselves of every means of improving our manufacturing quality and the adequacy of our engineering. This year, for example, we will sell approximately 10,000,000 appliances which represents roughly 30,000,000 new users (based on an average of 3 to a home). I sometimes feel that, just on the law of averages, we are very fortunate if we don't stub our toes in a few homes every day.

In addition, this whole situation is complicated by the fact that in the field of household appliances our products go into use where there is little or no knowledge and usually no particular interest in mechanical things, except from the viewpoint of service rendered. Certainly there is no skilled maintenance group readily available at all times, close by or on the premises. This can be contrasted to electrical apparatus sold for industrial and power use or to railroads, etc. for which almost invariably there is readily available on the site a trained maintenance organization, not only for emergencies but to carry on regular preventive maintenance. The situation is not helped any by the modern trend whereby household products are becoming more and more complicated, more automatic, and are designed to provide a wider range of service or flexibility. Our whole endeavor, including promotional work, is to replace the servant by completely automatic, robot-like appliances. I am more convinced every day that we should insist that the modern husband be required to have a short course in engineering before he is allowed to become a husband!

From the standpoint of service, a household user cannot drive her automatic washer into the neighborhood garage from time to time to have small adjustments made. Likewise, she often finds it difficult to get quick service and ready cooperation at her home when she tries to get a mechanic or serviceman to visit her and make some adjustments. With the unskilled operator, such adjustments and regular checkups are highly desirable. The situation is further aggravated by shortage of trained service labor and consequent lack of readiness to respond quickly to service calls. As a matter of fact I think users of household appliances often forgo calling a serviceman as long as possible because of unsatisfactory response and inability to get rapid action, and are inclined to continue with the unsatisfactory operation or performance of an appliance for long periods of time before they are willing to go to all the bother and fuss of trying to get someone to come out and make simple repairs. Naturally, the manufacturer's reputation suffers most in such circumstances. Here is one urgent reason for having a concentrated drive directed at quality by a special group with quality as its business.

There are some additional reasons for careful control of appliance quality. We have known for a long time that in the field of electrical household appliances, as indeed in many others, we must commit and freeze the design of a product, and frequently must install expensive manufacturing equipment—all representing a large investment—before it can be extensively tried out. On top of this, the warehouse may be filled with the newly designed products long before we can have the benefit of any widespread customer use. How often it is that a simple error, which could have been corrected during manufacture, is reproduced thousands of times and gets into field use before it is caught, with a tremendous cost both in dollars and customer goodwill.

This problem, of course, is well known, but it does take on renewed emphasis in the face of the ever increasing volume of our products. In addition to all this, many household items previously built in limited quantity, such as the dishwasher and the disposall, have now reached large volume and are subject to these hazards to a much greater degree than previously. I have discussed all these factors not because they are unknown, but as an indication of why those of us responsible for manufacturing and engineering results consider quality to be so important.

Let us consider now some of the specific responsibilities and the opportunities of an integrated Quality Control organization, as we see them, in a large manufacturing operation.

WHAT MANAGEMENT EXPECTS FROM QUALITY CONTROL

Any management group will necessarily look at any integrated functional activity mainly as a business venture. This means that it must be proved to be profitable from a dollar and cents standpoint. In an operation such as ours the expense of salaries, investment in equipment, the cost of carrying on experiments, and other activities of a large Quality Control organization are very considerable. I think that a Quality Control organization should and will be required to prove to management that it can be and is, in the long run, a profit-making organization with something to sell on which a profit can be made.

In the final analysis, I suspect this is about the only basis on which a Quality Control operation, as a separate integrated function involving added direct expense, can be sold to management.

Following are some of the most effective ways which, in our experience, show the greatest promise of a profit-making result.

1. Scientific Inspection Planning

Very naturally, one of the first things an organization of this type can, and should, do is to provide a carefully thought-out, scientific and statistical plan, covering all of the tests and inspection. This should start with all materials and parts produced by suppliers and carry on through the factory, beginning with labor operations of all kinds, with particular emphasis on fabrication as well as assembly, and in-

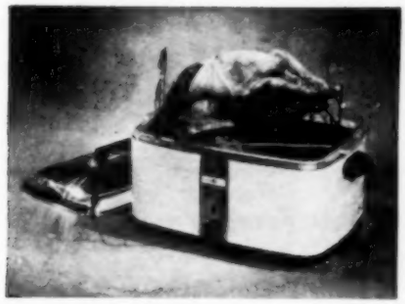


FIGURE 1

FIGURE 2

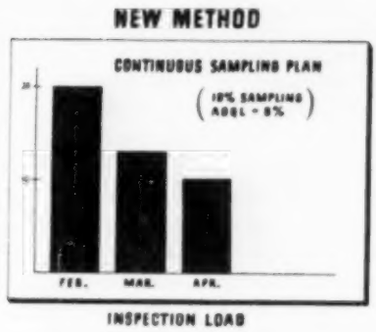


FIGURE 3

cluding final examination of the end product. This all adds up to a well planned sampling inspection which retains the necessary quality protection while reducing test and inspection expense.

Perhaps a few examples of the economies that can be effected in this fashion would be of interest. Consider our experience in the matter of the electric roaster, which we manufacture, and our problem of maintaining outgoing roaster quality. (Fig. 1) It was established that the cost of 100% testing of complete roasters, to determine whether or not they meet our temperature specification limits, would require test equipment costing in the order of $60,000. (Fig. 2) This prompted an investigation to determine how critical these limits really were. The study revealed a healthy safety factor and this fact, considered in conjunction with the known shape of the temperature distribution, made it clear that a low percentage could be allowed outside the limits without adverse experience in the field. This meant, of course, that a sampling plan could safely be considered. I am told by my associates that a Dodge continuous sampling plan was applied calling for 10% inspection and giving outgoing quality protection of 7%. (Fig. 3) Due to occasional 100% inspection required by the plan, the initial inspection load was 20% but soon dropped to 12%. It was anticipated that the actual percentage of roasters being shipped outside limits would be much less than 7%. This, as well as the protection afforded by the plan, was proven when an independent audit over a period of time disclosed that only 4% out-of-limit roasters were being shipped. (Fig. 4)

The economies of the reduced inspection are more or less obvious and a saving of $50,000 in test equipment was realized. It is sometimes implied that 100% inspection is justified to eliminate the 4% out of limits. The analysis in this instance indicated that such was not the case.

One of the most insidious effects of 100% inspection of simple elementary type products is the deadening effect on the person performing the work. Operators doing repetitive operations fail to catch defects occasionally because of fatigue, distraction, or the sheer monotony of the job. In our experience better outgoing quality is obtained, in many instances, on a statistical basis if the samples withdrawn are subjected to a completely thorough inspection which invariably can be carried out more deliberately and under much better conditions.

An illustration of this may be of interest. It has to do with the quality of an ordinary electrical cordset. An audit made of outgoing cordset shipments, in an investigation of field quality, revealed that an unsatisfactory percentage of defective material was getting past a battery of inspectors set up to provide 100% inspection at the end of the line. The installation of a continuous sampling plan on a conveyor belt, following the 100% inspection stations, resulted in stopping all shipments until the outgoing material was improved to the point where it satisfied the sampling inspections, and the outgoing percentage of defectives dropped to less than one-tenth of one percent.

The economies were brought about by the chain of events set in motion by this experiment. As a result of the hold-up in shipments, brought about by the sampling plan, an intense effort was made to reduce the defectives coming to the end of the line, and a systematic sampling of the individual machine operators making the cords was established. The source of the faulty work was quickly identified, and the corrective measures which resulted brought about the improvement shown in Figure 5. Not only was the quality improved, but most important in discussing any economies, production was increased 60%. (Fig. 6)

In our experience Quality Control, as a profession, has a wonderful opportunity in the field of improving highly mechanized methods for making inspection and tests. There are numerous automatic gaging devices now being used rather extensively in high production manufacture to completely check

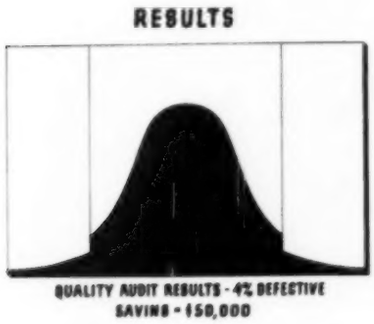


FIGURE 4

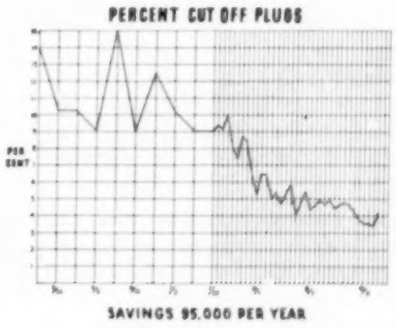


FIGURE 5

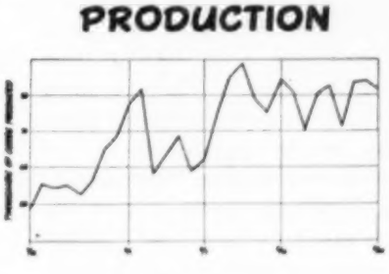


FIGURE 6

all the critical dimensions of component parts. Certainly the modern trend in industry is in the direction of mechanizing all kinds of operations to save labor—involving assemblies as well as parts and components—and there is an opportunity in test and inspection for the use of such methods.

As I see it, the Quality Control organization should function as an aggressive planning and methods group specializing in the field of inspection and test, with the full range of opportunities for improving efficiency. This involves not only the planning of operations involving labor, but new and radically different equipment.

Let us look at an example of another type of cost reduction brought about through systematic sampling, backed up by proper action. The Wire and Cable Division of our Company became interested in the possibility of reducing the number of turns or convolutions of steel strip per foot making up the outer covering on standard BX cable. At the time, these were averaging 47 turns per foot (see left hand side of Figure 7) while the minimum number of turns required by the specification was only 43. These extra turns served no useful purpose and, what is more important, required extra steel—adding to the cost of the steel and aggravating steel shortage conditions.

The Quality Control organization was again called upon to set up a regular sampling check—this time in back of each winding machine. It soon succeeded in reducing the frequency of defective runs which in turn brought about a reduction in the variability of the number of turns per foot. This, in conjunction with a regular sampling check ($n = 5$), allowed the winding machines to be reset so the number of turns averaged 44.8 (see right hand side of Figure 7). Operating in control at this level, only about 10% of the cable footage fell below 43 turns—and not very far below at that. Because of the approximate nature of this specification, such performance did not violate the spirit of the minimum-turns requirement, especially since average and range were continually checked to make certain that this percentage was maintained.

Such control methods resulted in a saving of $25,000 per year in a material in extremely short supply, at that time, with no fundamental change other than proper sampling inspection. Obviously, this is a fine profit return from so simple a procedure, and it proved that sampling inspection can pay off in cash.

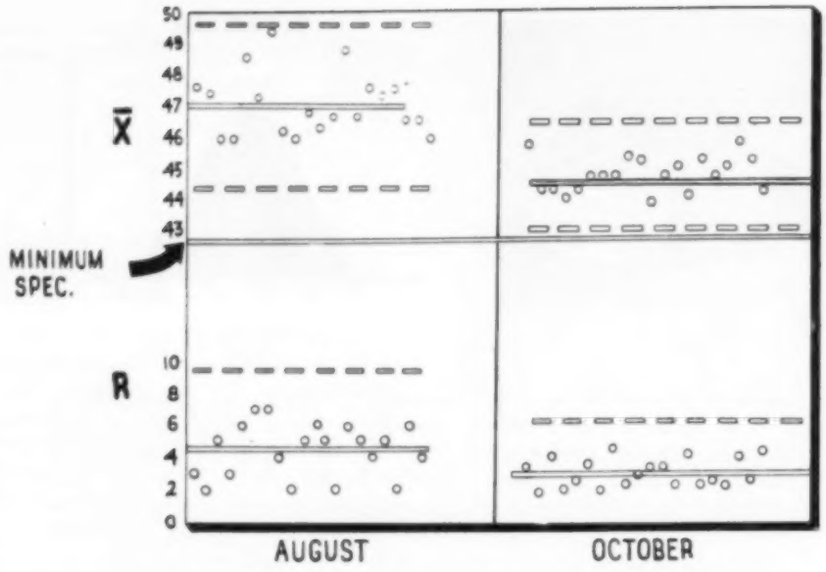


FIGURE 7—$\bar{X}$ AND R CHARTS FROM BX-CABLE PROJECT

2. Promotion of Operator Enthusiasm For Quality

In all of this kind of work the Quality Control man is not simply a statistician, dealing only with statistics: he is dealing directly with labor also.

Satisfactory employee relations require that the operator be sympathetic to management's aims, and this is particularly true where quality is concerned. We have found, I am sure in common with others, that there is no inspector like the conscientious operator whose attitude is right, who has been properly informed as to the requirements of the part or operation he is asked to perform, and who has been encouraged to call attention to errors in his own operation.

The Quality Control organization can be very helpful here by showing a direct interest in the operator's quality problems arising in machine-set controls and machine maintenance. At the same time the QC group will be building the operator's sense of pride and partnership in the whole enterprise and rendering a real service to management.

As an example, consider how the operator's enthusiasm was engendered by a group of Quality Control men in a machining operation on a part in our Trenton plant. The characteristic in question was the inside diameter of the rotor bushing shown in Figure 8. Because of failure to meet production schedules, a check was made of the ID's of all rotor bushings produced over a period of time. The investigation disclosed the situation shown in Figure 9 (the numbers represent hours of the day). Incidentally, the measurements were obtained from the feel of the "go" and "no-go" gage. The Quality Control group, working through shop supervision, discovered faulty tool practice and method of setting. These were corrected, and another 100% gage check was made, with the results shown in Figure 10.

The results were so satisfactory that it was decided that sampling inspection was all that was needed on the part. The practice was instituted, and the inspector soon began to notice a light check mark on the chart in advance of his checks. It developed that the operator had been curious to find out how she was doing, had found the gage method to be extremely simple, and so took her own measurements while the

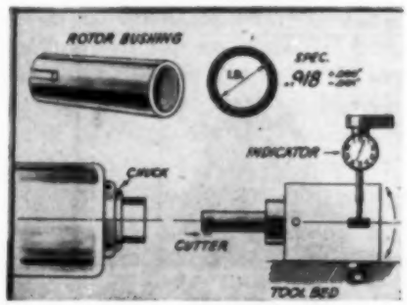


FIGURE 8

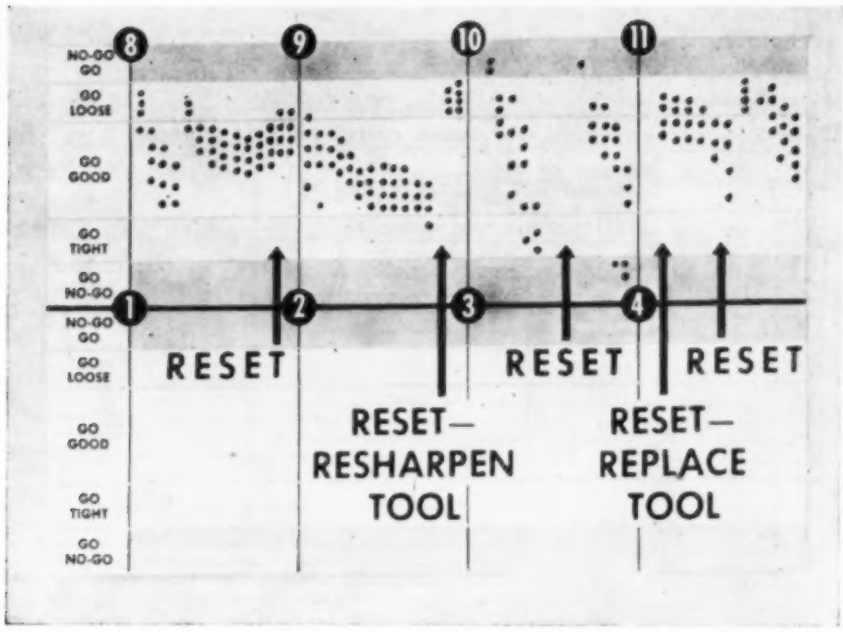


FIGURE 9—CHART OF PROCESS PERFORMANCE BEFORE QUALITY CONTROL STUDY

inspector was away from the machine. It developed further that she was only too pleased to do the sampling inspection because it enabled her to reset the tools at exactly the right time, reduced down-time, scrap and rework, and provided maximum production.

Amazing as it seems, production was actually doubled as a result of this investigation, and, of particular interest, there was an increase in the operator's take-home pay. Tool life increased from an unacceptable 100 pieces to a very satisfactory 1400 pieces. This illustrates what I have been trying to say so thoroughly, that it may be worthwhile to summarize what had been accomplished. (Fig. 11)

Note that the operator's responsibility and action heads this list. As I

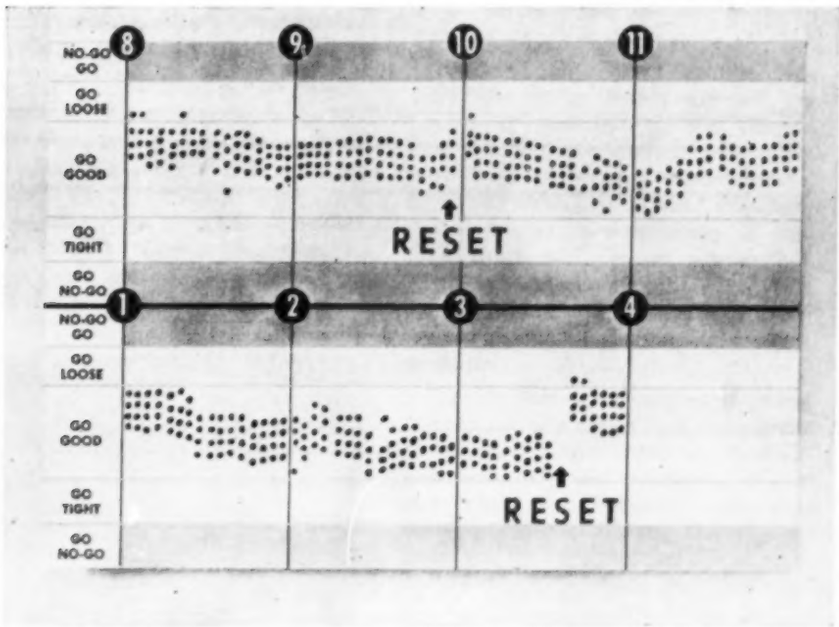


FIGURE 10—CHART OF PROCESS PERFORMANCE AFTER QUALITY CONTROL STUDY

1. OPERATOR RESPONSIBILITY AND ACTION
2. COMPLETE KNOWLEDGE OF MACHINE PERFORMANCE FOR ENGINEER AND PLANNING
3. HIGHER TAKE HOME PAY FOR OPERATOR
4. INCREASED PRODUCTION
5. SAMPLING INSPECTION
6. NO SCRAP OR REWORK
7. ADVANTAGES OF VARIABLE GAGE WITH PLUG GAGE
8. CORRECT TOOL PRACTICE
9. EASY SUPERVISION

FIGURE 11

pointed out before there is rightfully a trend in industry to take more and more responsibility away from the operator by mechanizing means. This is a natural outgrowth of the industrial revolution, of course, but nevertheless we must not forget that there are many times when the cooperation of the operator can be tremendously important in improving results. Quality Control can act perhaps as a powerful catalyst in re-establishing the pride in workmanship as a contribution to good quality in these instances.*

A word of caution is in order here; namely, that Quality Control must counteract vigorously a normal tendency on the part of any operator to be suspicious of a Quality Control man on the basis that his only function is policing and reporting bad performance. This provides Quality Control with an opportunity and a responsibility in the field of employee relations, and one tactic that will be helpful, I am sure, is to find some means of compensating an employee for calling attention to a bad part the instant he makes it, rather than penalizing him for the error, the more usual practice. I, for one, believe that on the average the operators much prefer to make good parts, and are quite willing to throw out poor ones, particularly if we can make it to their advantage to do so.

3. Establishment of Good Vendor Relationships

All reputable manufacturers for a long while have spent large sums to improve the efficiency and quality of parts and processes in their own factories, but I suspect, in many instances, that they accept parts or material from outside vendors on the best basis possible without any particular concern as to the method employed for producing these outside parts or materials, or the method of controlling quality in the vendors' plants.

* See for example "Reestablishing Operator Responsibility for Quality," Wyatt E. Lewis, **Conference Papers,** p. 233.

The importance of this phase of the manufacturing cycle is best emphasized by pointing out that some 60% to 70% of the cost of the end product, in a large number of cases, is made up of materials or parts processed in outside plants. We have actually discovered cases where vendors quote us a price on parts which includes a factor based on its rejection record. In other words, if they find we regularly reject 15% or 20% of all units shipped to us, they allow for this rejection rate in the cost, and we have been paying the bill. We have encouraged our Quality Control organization to devote as much time as possible to vendors and their plants. We consider their facilities as important as our own factories.

One possibility in this connection is the inclusion of a sampling and test specification in the purchasing specification which will completely inform the vendor as to the exact basis on which we will accept or reject materials. Figure 12 is the type of form which we have prepared for this purpose. It lists all important specifications with the acceptable quality levels that apply. These are then attached to the blueprint forwarded to the vendor and are considered as part of the purchase order. Note that at the bottom of the form it is clearly indicated that mixed lots may be returned to the vendor to be sorted at his expense, if the percentage of defectives exceeds the listed AQL.

It is quite possible to convince a vendor to make his own sampling tests to insure that the submitted product conforms to specifications, and to supply us with the results. Figure 13 is an example of a record furnished us by the vendor on a lot of drain hoses used for some of our washing machines. Such records, being about reduced rejection losses, give the vendor an opportunity to improve his prices for our benefit. In the end he, himself, usually has lower costs and certainly many less uncertainties.

One other service which the Quality Control organization can provide our vendors is to establish the routines for controlling their own in-line quality most efficiently. It is only logical to expect that any improvement in efficiency in manufacture of a vendor eventually results in lowered costs to us.

The opportunities in this entire purchasing program are, in my judgment, tremendous. To realize them, the Quality Control engineer must make certain that the quality standard is crystal clear

Form G-8869 11-48

PART NAME AGITATOR CAP INSERT DWG. NO. K-5400582 REV. 2

QUALITY CONTROL INSPECTION PLAN Per S.I. 201483 Sec. C

HOME LAUNDRY EQUIPMENT DIVISION GENERAL ELECTRIC CO. BRIDGEPORT WORKS

Issued By: A. U. Pison Supersedes: 11/10/48 Effect. Date: 12/2/48

CHARACTERISTICS AND ACCEPTABLE QUALITY LEVELS (AQL)

Item No.	TEST REQUIREMENTS	CODE	CRITICAL CHARACTERISTICS	AQL	MAJOR CHARACTERISTICS	AQL
1	Material BILHCF	U	5/16 - 18 thread	2½B	1/8" thickness	4B
	G.E. - Works					
2	Laboratory		.375 Dia.		.375 Dia.	
3					1/32 x 45° chamfer	4B
4					1 3/8" Dia.	
5					Burrs	4B
6					Knurl	

Code letter for test and AQL's are for G.E. internal use only.

All parts should be to drawing specification in all respects. The most important characteristic to be checked with their Acceptable Quality Levels are listed above. Inspection by G. E. Company may be made by recognized sampling methods. Lots exceeding the AQL per cent defective as indicated by the sample inspection will be rejected and returned to the vendor or, if necessary to maintain production, will be sorted at his expense. The requirements of this Inspection Plan are a part of each purchase order.

FIGURE 12—SAMPLING AND TEST SPECIFICATION FORM FOR PURCHASE ORDER

VENDOR CERTIFICATION OF QUALITY

GENERAL ELECTRIC CO.

Report No. _____

Order No. _____

Date Shipped _____

Quantity _____

Part Name: _____ Dwg. No. _____

Vendor: _____ Address: _____

SPECIFICATION	NO. CHECKED	RESULTS	REMARKS

SIGNED _____

TITLE _____

MAIL THIS REPORT TO: GENERAL ELECTRIC COMPANY
QUALITY CONTROL SECTION
AUTOMATIC BLANKET AND SUNLAMP DIVISION
1285 BOSTON AVENUE
BRIDGEPORT, CONN.

FIGURE 13—FORM FOR VENDOR CERTIFICATION

Meet Joe Spoilage
Do you know him?
This guy cost us $530 last month
Who is he?
This industrious chap shoveled $760 worth of dirt onto contacts last month.

FIGURE 14—QUALITY CONTROL POSTER

both to the supplier and himself, as well as to his own company's organization. He should constantly bring to the vendors' attention more efficient process controls which tend to reduce costs and build quality into the product. In many cases, we often gain sufficient confidence, when a vendor cooperates in this manner, to accept his material with only an honesty check. This is the goal —everybody is bound to profit.

4. Assurance That Quality is Built into the Product

There are some functions of Quality Control which are not so directly susceptible to a dollar and cents analysis, but I would not want to pass these up without discussion because they have considerable value as a useful product of our Quality Control organization. One of these was hinted at earlier and has to do with the promotion of quality-mindedness throughout the organization, particularly direct labor. Typical of what I mean are some of the efforts of our Automatic Blanket and Sunlamp Division, through the use of posters (Fig. 14), to reduce spoilage and improve outgoing quality. Sometimes publicity of this simple character is the best and only type of approach to poor assembly quality. Through this medium we can encourage the cooperation which we have got to have to eliminate the defective work.

We think a Quality Control organization should continually expound the philosophy practiced by the Chinese and their Chinese doctors—paying for prevention of illness instead of cure. Expressed in Quality Control language, this all has to do with setting up routines which will prevent substandard parts and units from passing the point where they are made and finding their way into other components or the end product.

The application of additional labor to parts already defective is pure waste of money, but more important, if defective material is not discovered at an early stage, it is frequently never discovered until it is too late. This all supports the oft-repeated statement that quality must be built into a product step by step, and can never really be inspected into it.

A simple illustration bearing on this point is our automatic blanket—note in particular the crimped terminal in Figure 15. If this crimp is not properly made, the customer will eventually have an open circuit blanket. Poor work in this instance must be discovered before the wire is shuttled into the blanket, or it will come to light in the form of a complaint from the field.

FIGURE 15

This operation involves a very minute amount of labor expense, but the repercussions due to a poor job can be disastrous. To detect defective work, our Quality Control organization set up a completely destructive pull test on a sampling basis, immediately following the crimping operation. Individual breaking strengths were plotted (Fig. 16) and automatic, corrective action arranged for according to a prearranged sampling and control plan.

5. Setting of the Quality Standard

The Quality Control organization in our department has the prime responsibility of seeing that proper standards are drawn up for every appliance. Figure 17 shows a check list covering all dimensional and performance specifications which Quality Control has issued for one of our products. A large number of these specifications have been set down by the product designers, but generally Quality Control specifies detailed appearance requirements, acting as the customer's representative in this regard. In all cases, it is the definite obligation of Quality Control to verify all specifications and translate them into a standard by setting down the extent to which the product must meet these limits at every point in the process. In other words, quality levels are established. It may seem surprising to learn that some of these lists are as much as ten pages long.

In line with the above, to be specific, we believe that Quality Control should check all dimensional tolerances at the blueprint stage. There are also times

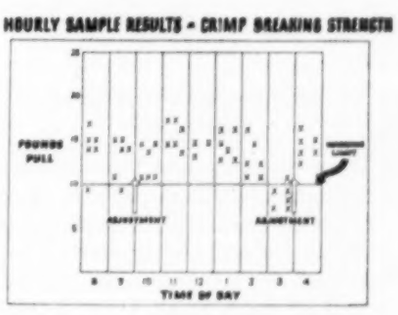


FIGURE 16

when this group may assist in determining specific limits through design of experiments and through conducting special experiments in laboratories set aside for this purpose. This involves running special tests such as those which are made to determine the effect of temperature and humidity on our automatic blanket control, and the correlation of this performance with field results. Such a program frequently makes possible an accurate prediction of the expected field results.

Still another possibility is in the extended life-testing by Quality Control. There is nothing new in life-testing as such, but here is another opportunity of having Quality Control make an independent life-test beyond those ordinarily carried out. This can be considered one of the most important controls of outgoing quality. It is the acid test which will signify reliability of appliance performance in the home.

In some instances, an ever-improving standard can be brought about by the close coordination of quality control results in every phase of the process. A case in point has to do with the dirt circulating or the residual dirt contained in the compressor of our G. E. refrigerator unit. The filter on the right in Figure 18 is the result of our best effort of a year ago and was regarded as fairly satisfactory considering the mechanism involved. Our Quality Control group, however, was not satisfied and continually tried to improve and increase the quality in the machine. It tackled each component part, piece by piece, to reduce contamination. Through its efforts in this direction, it was able to bring about the filter on the left. Now this is the standard, and Quality Control tells me they will soon replace it by an even tougher one. I think this example well illustrates what can be accomplished by a separate, independent group of people trouble-shooting where the occasion demands and possessing the time to see a problem through.

6. Coordination of Quality Problems

There are some other rather general requirements which we think are properly demanded of a specific group working in the field of Quality Control. Everybody in an organization readily recognizes the responsibility in the matter of quality, but there are many instances where no one completely understands who is responsible for action in emergencies or under other circumstances requiring specific action bearing on quality. Quality Control must take the initiative in analyzing all such situations, rapidly, without bias, and in determining who can best take action in these situations.

Quality Control stands in the center in relation to all other operating groups. (See cover picture, this issue.) It can enter the picture in any position of this cycle when a quality problem arises, and see that the most expert talent is brought to bear without buck-passing, and it can keep the wheel turning. But it must develop sufficient confidence so that its help is sought, especially by production groups, when production is down and extra costs are soaring.

CHECK LIST FOR RATING PLAN

QUALITY CONTROL AUTOMATIC WASHER

I.	Operational Defects		40%
	A. Mechanism		
	1. Agitate power	5.00	
	2. Start spin power	8.00	
	3. Full spin power	5.00	
	4. Torque	3.00	
	5. Resistances (each)	2.00	
	B. Tub and Apron Assembly		
	1. Loose screws in Tub flange	.25	
	2. Suds kill Baffle screws loose	.50	
	3. Suds kill Baffle lockwashers missing	.50	
	4. Suds kill Baffle screws corroded	1.00	
	5. Suds kill Baffle screws stripped		
	C. Dole Valve		
	1. Water Temp. Control (each)	10.00	
	2. Flow Control	3.00	
	3. Inoperative	25.00	
	4. Noisy	5.00	
	5. Poor shut-off	25.00	
	I. Circulating and Drain Pumps (Demerit each pump)		
	1. Noisy motor	3.00	
	2. Inoperative	30.00	
	3. Loose through bolts	3.00	
	4. Defective motor leads	1.00	
	5. Lead through housing and adapter	2.00	
II.	Appearance Defects Other Than Paint		20%
	A. Cover Assembly		
	1. Dented	3.00	
	2. Trim Band not tight	2.00	
	3. Trim Band wrinkled	2.00	
	4. Trim Band burred	2.00	
	5. Trim Band poorly finished	3.00	
	B. Apron and Back Panel		
	1. Wrinkled	1.00	
	2. Dented	3.00	
	3. Poor fit with cover	3.00	
	C. Controls		
	1. Not horizontal	2.00	
	2. Poor lettering on dials (each)	.50	
	3. Discolored dials	1.00	
III.	Crating		20%
	1. Suspension blocks loose	5.00	
	2. Crate bottom loose	5.00	
	3. Old style crate	20.00	
	4. Nails missing	.50	
	5. Nails mislocated	.25	
IV.	Condition of Paint		20%
	1. Orange Peel	3.00	
	2. Rough Paint	3.00	
	3. Too Thin	3.00	
			100%

FIGURE 17—CHECK LIST FOR RATING PLAN

7. Channeling of Quality Information Through Organization

Another related function is to provide an information network to carry quality ideas and ideals throughout the organization. There is always a feeling of security in the knowledge of the existence of a fast-working network which can be relied upon to transmit vital information of great importance to the point where it can do the most good. Over this network goes information covering field reports, relating to users' satisfaction, or lack of it, the results of laboratory tests, or the results of sampling on production lines. Over this network should go all experiences of common interest cutting across operational

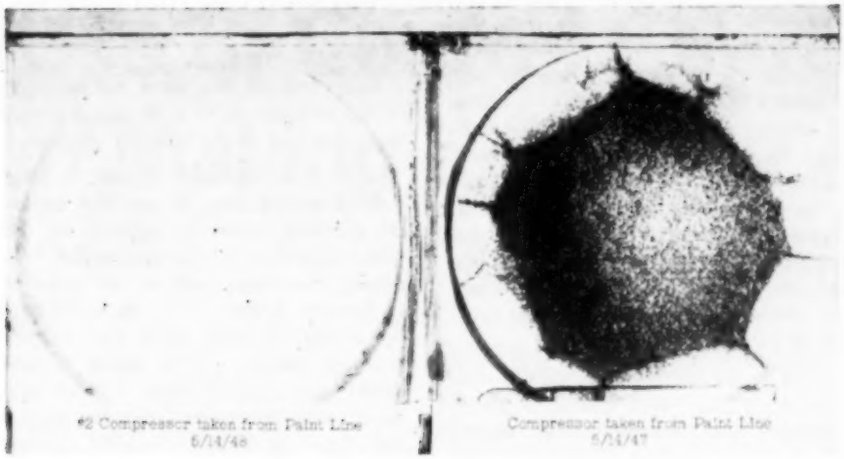


FIGURE 18—IMPROVEMENT IN COMPRESSOR FILTER

FIGURE 19

lines. Through these channels also, information is carried on all quality problems to those to whom it is essential or necessary.

Another phase of this reporting occurs when we introduce a new product. We usually experience at such times a rash of reports on factory tests, field experiences, customer reactions, etc., which often are not well planned and need coordination to be used to best advantage. We are placing on our Quality Control organization the responsibility of coordinating such information, boiling it down, and seeing that it gets to the point where it will do the most good.

8. Measurement of Quality

I would not want to close any discussion on Quality Control without expressing appreciation of the value of a single quality rating on a product. This involves a separate quality audit covering characteristics on the check list of the type shown in Figure 17. Demerits are assigned, a rating is computed, and a report is issued. (Fig. 19) We are finding that this information is a powerful tool to management.

In our judgment, it should be made available to the commercial organization if the relative quality of our outgoing products can be determined with confidence. Engineering and Manufacturing find such a rating useful in getting them off the hot spot when the rating curve shows quick restoration of quality after a period of distress. This information enables the commercial organization to talk confidently with customers, particularly after periods of dissatisfaction. Evidence at hand in the form of a quality rating shows that they know what they are talking about. Quality as an identifiable ingredient in a product is of great commercial value. To rate a product by a simple numerical rating is not easy, particularly on new products where there is no past history. A rating will have value only if there is belief in its accuracy, confirmed by field results.

Some of our groups have been able to use these ratings as a score sheet to develop competition between sections or departments, even to the extent of giving prizes—a box of cigars, for example—for the best rating. Such striving has the very practical result that everybody becomes quality conscious, and the quality rating and quality go up together.

WHAT QUALITY CONTROL HAS A RIGHT TO EXPECT FROM MANAGEMENT

Having dealt with the demands made on the Quality Control organization, I believe that it is only right to comment on some of the things that a Quality Control organization has a right to expect in return. I am dealing only with those things which seem important in making an efficient and effective operation in this activity.

First of all, it seems to me that the Quality Control organization has a right to expect that it will be fully identified as such—as an integrated unit, standing on its own feet, and not as a part of an engineering or manufacturing operation, and certainly not as part of an inspection setup. It should be identified as an organization capable of returning a profit on the investment made in it, and as one should be properly represented at top management levels.

In our department each division Quality Control engineer reports directly to the manager. It is intended that he be on a par from the point of view of salary and responsibility with engineering, manufacturing, and sales heads. In addition, the division Quality Control engineer reports functionally to the engineer of Quality Control of the department. He, in turn, reports to the departmental manager of engineering and manufacturing who is responsible to the vice-president and general manager of the department. Thus, Quality Control can obtain executive action through a number of channels at its discretion.

We believe this group is entitled to its own offices, and to its own laboratory to whatever degree can be justified for quality purposes. We believe members of this group should have a title of Quality Control Engineer, or some similar title.

We feel that they have a right to ask for inclusion in the discussion of engineering plans, product development activities, manufacturing program, etc.; that they should be given repeated opportunity to sell their services and the things they produce on a business-like basis. I would like, particularly, to emphasize the importance of selling down in the organization to those men on the floor, who are responsible for getting out production, rather than to top management.

These opportunities would take the form of being included in all kinds of presentations, bearing on functional groups of the organization as a whole, or to other functions in the organization. The Quality Control group needs to have the opportunity, particularly, to prove to those groups down on the floor that it is not a policing group primarily, there to obtain information and carry tales to management, but that it can be helpful in serving the men on the floor, all of them, in getting out production.

Quality Control has a right to sell itself as a service, as part of the team—freely entitled to all facts and all information on the basis that it can be trusted to use such knowledge with discretion and not as a listening agency or policing force.

I think Quality Control has a right to demand of management sufficient backing in the matter of quality, particularly when situations become so acute that, in its judgment, the matter of quality is determining above all others. It requires a great deal of confidence on the part of management to shut down a factory, or seriously curtail its production, purely on the basis of judgment of the individuals of the Quality Control organization, without actual field experience, and bearing in mind the urgency of production demands. Nevertheless, there are times when Quality Control must resist strongly, and may even have to demand backing by top management.

I think that Quality Control should be encouraged to expect a professional status. There are times when management can be called upon to set up meetings for Quality Control before manufacturing, engineering and commercial representatives. It seems to me that Quality Control men acquire stature in the industrial field only if they have opportunities at regular intervals to sell their accomplishments, and a chance to prove that they really are a profit-making organization.

Certainly they should be encouraged to make presentations before regional and national field meetings. Management can be sold on the value of such participation, from the standpoint of advertising, or increased prestige, brought about by emphasis on Quality Control. Any activities which permit better understanding of Quality Control tend to raise quality, which has value to all manufacturers in improving the good name of a class of products. All manufacturers, as buyers, benefit from Quality Control activities among vendors.

THE QUALIFICATIONS REQUIRED AND THE OPPORTUNITIES FOR QUALITY CONTROL AS A PROFESSION

It would seem appropriate to mention some of the qualifications needed in the Quality Control organization, as we see them.

Seriously, it seems to me that this field of industrial activity represents a challenge on as wide a plane as any function I know of. Certainly, a Quality Control man needs to be an engineer, technically trained, or at least technically minded. He certainly needs to be a diplomat, because here he is, jammed in between engineering and manufacturing on one hand, and the customer and management on the other, with the commercial organization looking at him with a critical eye.

If he is not discreet, he will be considered as one who plans to sit in judgment and find fault with others, and this is, at best, a difficult position.

Salesmanship is certainly needed, particularly because he is at his best when his services are demanded by those he can best serve, rather than being forced on them. If he fails to sell, he can become a source and center of a great deal of controversy, bringing about much irritation and much misunderstanding.

We have to say he must be a good administrator, because he must play an important part in the organization, and has a specific group of his own to direct.

Operating such an organization, in the midst of other functions, and associated with operations which may be classified as critical, or policing, without clashing, is no small task.

In general, he needs all the attributes of a well-rounded individual, and certainly our man must have patience, good judgment, a sense of true values, and I believe, at times, a very strong sense of humor. He must know when to compromise and when to be persistent.

Above all, he must be careful not to acquire a reputation as a carrier of tales, carrying the shortcomings of everyone to superiors, or to others, and at the same time he must be capable of giving out information properly and correctly to those who need to be informed.

And as if all this were not enough, he has to know quite a bit about manufacturing and manufacturing methods.

Now as to the opportunities. It goes without saying that, in the final analysis, progress primarily depends on the man, regardless of his assignment. We should, therefore, look at the practice of Quality Control, first, as a field of opportunity in itself for a man of outstanding ability. With some of the duties and opportunities I have outlined, with particular reference to the fact that we believe Quality Control should be represented at high management levels, there is opportunity in carrying increased responsibility in this function, with proper recognition, both as to income and responsibility.

In our organization, we feel that the practice of Quality Control is a very effective training ground to develop men of outstanding abilities for other responsibilities. Bearing in mind all of the qualities I have outlined, it seems to me that the individuals who successfully discharge the responsibilities I have described, should be outstanding material as managers, with responsibilities in any related field. Certainly, from the broad viewpoint of a channel or avenue of experience, leading to responsibility in any field of management, I can think of no more effective one.

As I have already pointed out, Quality Control is a good business venture, and as a separate, worthwhile identity in the operation, is being more and more recognized by management. As this continues to grow, I, for one, believe it will become a more and more important function in the industrial scheme of things.

A Quality Control engineer roams wider in his responsibility, both across the functions of engineering and manufacturing, and the region between the vendor and the customer, than most any other functional group. I can think of no more broadening experience, particularly when we think that in these activities he has the unusual opportunity of making active contact with large numbers of people, carrying major responsibility in all fields and operating as part of a big industrial machine.

Outstanding men in this activity are sure to succeed in one way or another.

NOTICE

The Index of Vols. I-IV is a ready reference covering material published in IQC July 1944-May 1948. Extra copies available at $1.50. Order from

Alfred L. Davis, Treas., ASQC
65 Plymouth Ave., South
Rochester 8, N. Y.

Use of Control Chart Techniques in Making a Quality Audit—Part I†

BONNIE B. SMALL

WESTERN ELECTRIC COMPANY, INC.

This paper describes an application of the Shewhart control chart (Ref. 1, 2) as part of a quality assurance program at Western Electric, in which the control-chart techniques are used, not primarily for purposes of shop or process control, but to provide an engineering check on the quality of product ready for shipment. It is taken from a series of similar applications, covering a number of electrical transmission instruments of more or less complex design which are manufactured for use in the telephone system. These instruments include transmitters and receivers of many varied types. Some are used on the subscriber's premises, some in central offices, others in functions that are highly specialized. One such instrument has been selected as a typical example. We may call it an instrument of Type X.

DESCRIPTION OF THE INSTRUMENT

This instrument is a fairly complex unit consisting of some twenty different parts and partial assemblies. It is manufactured under a specification which imposes a large number of requirements. Some of these are electrical in nature, such as efficiency of transmission at specified frequencies, freedom from unwanted output components, electrical resistance, and so on. Such performance or "end" requirements are readily checked on the completed unit by a series of electrical tests.

In addition there are many dimensional and workmanship requirements, which have a more or less direct effect on the performance or life of the instrument, or its interchangeability with other units in service. Some of these are accessible to inspection in the finished state, but by far the greater number have to do with internal parts. Internal requirements include the inside and outside diameters of the piece-parts themselves; the total height of assemblies made up of several components; the depth and spacing of steps and seating surfaces; dielectric strength of insulated areas; thickness and height dimensions; concentricity of assembled parts and adhesion of cemented surfaces; tightness of assembly; freedom from foreign matter and burrs; continuity of plating or finish; and a host of other items of a similar sort. Requirements like these are checked by the Shop at various early and intermediate stages of manufacture; their nature is such that minor failures to meet them might easily escape detection in the tests on finished product.

Nevertheless it is of particular importance, in the type of instrument under discussion, that product flowing to the field should have its internal dimensions in good control. The present paper is concerned with a use of the Shewhart control chart to provide assurance that this is so.

IMPORTANCE OF CONTROL

Telephone instruments represent a class of apparatus in which there are economic as well as engineering reasons for maintaining a particularly close control. These instruments are manufactured at the rate of millions per year; and they are used in locations so widely scattered that the cost of repair or replacement, in event of a failure in service, is high. Thus, many of their quality characteristics have a significance which extends beyond their obvious effects at the time of manufacture.

Dimensions, for example, which affect the spacings of an electro-mechanical vibratory structure, may influence performance in ways that are subtle and not always easy to define. Their influence is seen in better or more uniform behavior, a longer life in service, a minimizing of maintenance and of service troubles. Moreover, if such dimensions are controlled, they facilitate the solution of fundamental engineering problems, such as might arise, perhaps, from an accumulation of adverse factors in a combination of circuit conditions, as in multi-office and repeater connections. To use the Shewhart phrasing,* these characteristics refer to quality in its relational sense: that is, the instrument is part of a telephone circuit, and as such it contributes to the transmission properties of the circuit as a whole.

It is not always feasible, from an economic or a technical point of view, to provide direct or specific tests for the presence of all these ultimate characteristics in the product. Reliance must be placed instead on a close control over the parts and the manufacturing process, in conformance with the intent of the design.

In the case of the instrument we are discussing, something like 17 of its internal characteristics are considered to possess this engineering significance, and to require this close control.

MANUFACTURING CONTROLS

Units of Type X are manufactured on several conveyor-type assembly lines at a fairly rapid rate. Like other Western Electric products they are produced under a plant-wide program of quality control. The manufacturing controls, whether they are charts or other controls associated with statistical sampling plans[3], begin with the materials, continue at the machines, and follow through the process to the finished product. There is a final Shop inspection, which includes performance tests, and then the completed and inspected product is ready to be shipped.

† Presented as the #23 Clinic Paper at the Second Midwest Quality Control Conference, Chicago, Ill., June 1947.

* W. A. Shewhart, "Some Aspects of Quality Control," Mechanical Engineering, Vol. 56, Dec. 1934.

So much for the established operations of shop and manufacturing control. The subsequent audit, which is the topic of this paper, is concerned primarily with control from the overall or engineering point of view. Optimum control, as we may call it, means adequate control of all the parts and functions of this complex process, not only in themselves but in relation to each other. It means the maintaining of suitable statistical interrelationships between the various frequency distributions; and this requires, among other things, that the immediate control measures adopted by the Shop at different stages should carry through effectively into the finished product.

To collect appropriate data for such an audit we dismantle small but regular samples of completed units, and make an independent check of essential characteristics. The audit is transformed from a passive check to an active, controlling influence on product, when these data are made use of through control-chart techniques.

The following examples will illustrate some of the effects of such an active study on the quality of our transmission instrument of Type X.

CHARACTERISTIC A

Consider first a certain internal dimension, which we may call Characteristic A. Figure 1 shows the history of this characteristic for a period of more than a year, during which we have taken 200 samples of five. This is a typical conformance-control chart[4] in which, for the sake of simplicity, some of the conventional lines and symbols have been omitted. The upper curve consists of averages of samples of five, and the range or spread of each sample is plotted below. Specification limits are shown as horizontal lines extending through the margins, labeled "Max." or "Min.". The other lines, solid and broken, are the statistical limits for 3-sigma conformance-control. These limits are usually computed from the known standard deviation of the process; which, in the case of Characteristic A, had already been determined from a previous study. A large circle identifies a period of trouble, when conformance or control was lost or threatened, and special action was being taken to restore it. On the original charts these circles are drawn in red.

Figure 1 tells us that Characteristic A has been, for the most part, in an excellent state of control. But during the circled period the range chart showed abnormal variations, indicating the presence of "assignable causes" in the process; and at the same time the chart for averages had points falling out of control on the minimum side. Attention is called to these by a number of crosses and checks which, on the actual charts, are respectively red and green. A cross means that the point is outside of 3-sigma limits. A check is an indication of a highly improbable run[5] or combination of points. Since this is a conformance-control chart, with limits designed to test conformance to requirements, points like these told us that it was extremely likely that product was or would be nonconforming, with respect to Characteristic A.

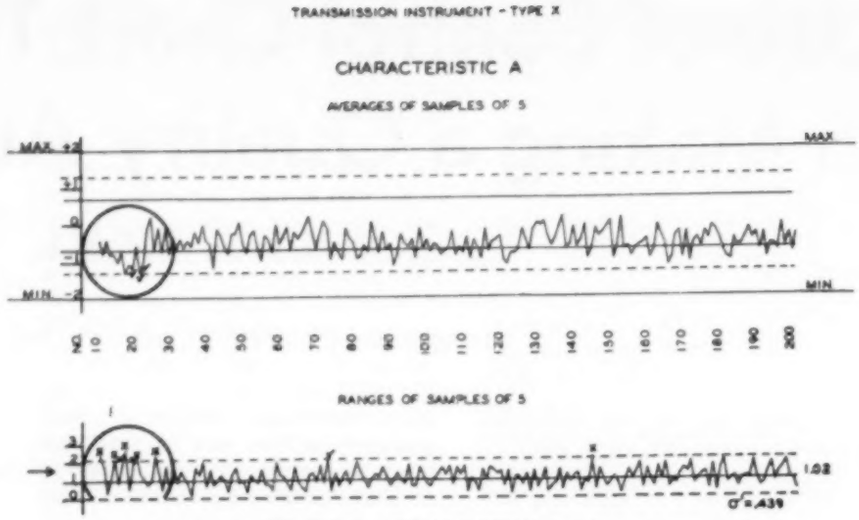


FIGURE 1 — CHARACTERISTIC A

INVESTIGATION OF TROUBLE

Figure 2 shows the period of trouble in a more detailed form. Small dots give the individual readings in each sample. Two of these, which fell outside of limits, are heavily circled—again, on the original, with red. The range and average points, the control limits and indications of lack of control, are the same as in the corresponding period in Figure 1.

It is clear from this that the downward trend in Characteristic A had been permitted to continue until defective material was beginning to be produced. But long before that time the first points out of control had aroused suspicion, and investigation was already under way. Since these were parts which had been inspected by the

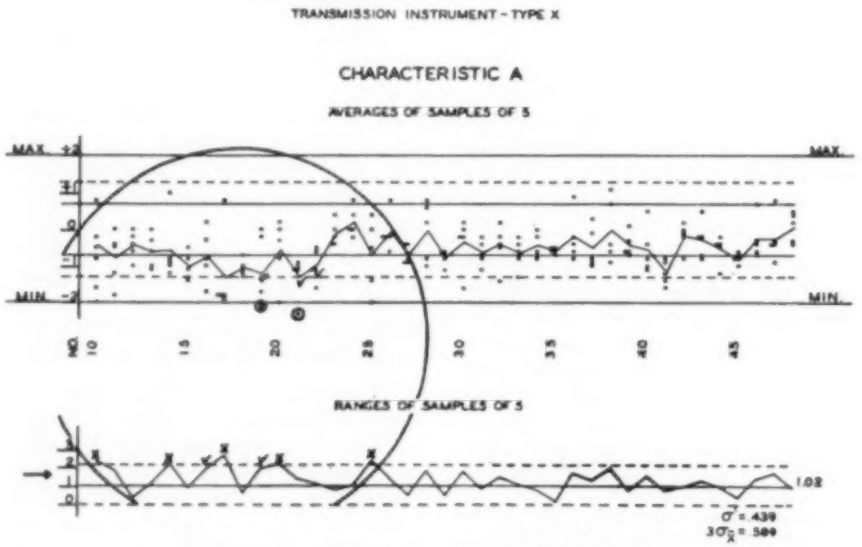


FIGURE 2 — DETAIL OF CHARACTERISTIC A

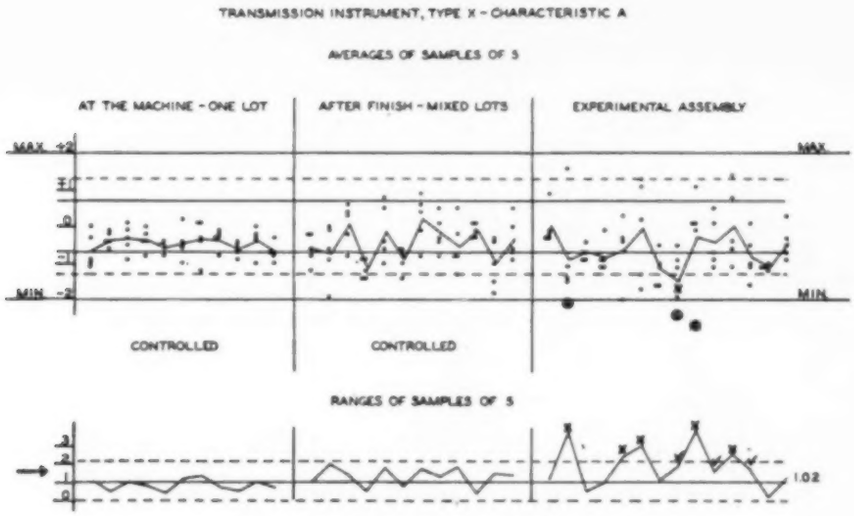


FIGURE 3 — IDENTIFICATION OF TROUBLE

Shop, and subjected to its regular process control, the Shop inspection records were consulted first for indications of impending trouble. When these failed to show the out-of-control condition, and spot checks failed to locate or identify its source, parallel control charts were run at several major stages in the process. Three of these are reproduced in part in Figure 3.

Here we see, in the first section, some typical parts as they were being made at the machines; then a mixed group of parts as they were received from the plating department; and finally a group of those same plated parts after they had been assembled into units. Even a casual inspection of this chart makes it evident that control was being lost at the assembly line itself.

IMPORTANT DISCOVERIES

This chart led to a discovery of some importance. Parts which had been properly controlled to begin with were being given a glancing blow during one of the final assembly operations. This was deforming the metal and pushing it inward, affecting the ultimate values of Characteristic A. The cause, of course, was readily determined. It proved to be of an unusual and unexpected nature, and appropriate steps were taken to make sure that it would not recur.

But there was another discovery also, more significant than the effect on Characteristic A. It was found that the glancing blow could scrape off tiny particles of metal, which might later find their way into a vulnerable portion of the unit and result in impairment of transmission in the field. This latter condition, if it had gotten into the product, might well have caused trouble of an expensive, baffling and intermittent kind.

The case of Characteristic A illustrates one of the important functions of a final engineering audit which makes use of control-chart techniques. The manufacturing controls had been applied, and properly so, at the machines themselves; and the Shop had no reason to suppose that undesirable changes might occur later in the process. The trouble that affected Characteristic A had never been foreseen and, it is hoped, will never appear again. But when the unforeseen occurred, it was promptly detected by the chart.

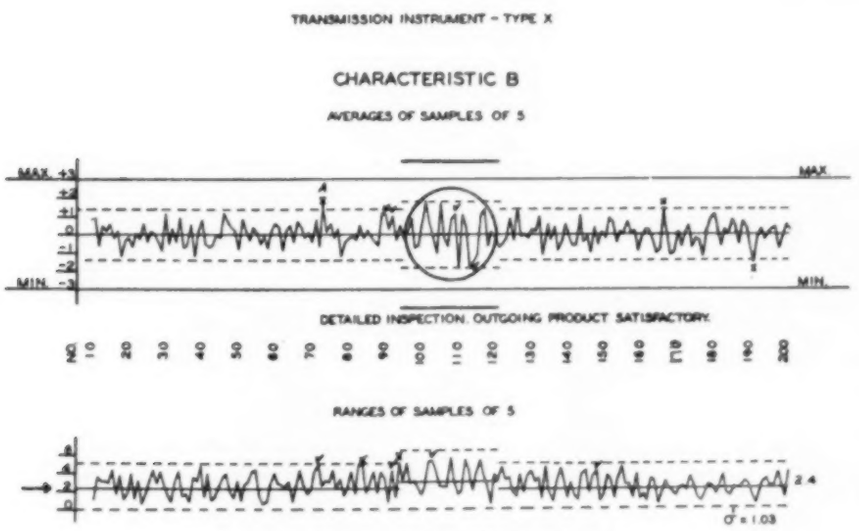


FIGURE 4 — CHARACTERISTIC B

CHARACTERISTIC B

Now let us look at another internal dimension, which we may identify as Characteristic B. Figure 4 shows that it started out in good control. But a point fell out of control at A, and this was followed by some extremely improbable runs. At the same time the ranges in our samples increased, so that their average was considerably higher than it had been before. All these were indications that something significant had happened in the process, which had appreciably increased its spread. When this was verified by a preliminary investigation, heavy lines were added on the chart, outside of the tolerance limits, as a warning that the process variability had become too great. On the original chart, according to our custom, these warning lines were drawn in red.

It will be shown a little later that the distribution of this characteristic had, in fact, taken on a tri-modal form. The average range of samples of five had increased to 3.1 units, and this was .7 units higher than what we may refer to as the "critical range"*, which is shown by an arrow in the lower left margin. When the critical range is exceeded, some of the product is sure to be defective unless steps are taken to reduce its spread. Since Characteristic B was a very critical dimension, and since 100% inspection was undesirable from an economic standpoint, it was important for this condition to be corrected with the least possible delay.

* Value such that 6σ or $6\bar{R}/d_2$ = specified tolerance, where $d_2 = 2.326$ for samples of $n = 5$. See (2).

It has been our custom to keep these auditing control charts conveniently displayed, where they are accessible to the production, inspection, engineering and equipment-maintenance personnel. Thus the appearance of trouble in Characteristic B was the signal for a concerted, cooperative investigation of its causes by representatives of all the interested groups.

THE SHOP'S PROTECTIVE CONTROLS

Figure 5 shows how the Shop's protective controls functioned while the investigation was in progress. At point A the sampling plan began to reject the product, and 100% inspection was begun. In spite of this, three defective assemblies (marked with circles) slipped through into our samples. At point B the causes of the trouble had been discovered and confined to one of the conveyor lines. On this line the detailed inspection was continued for some time, while on the others the Shop resumed its normal sampling procedure.

IDENTIFICATION OF CAUSES

Now let us return for a moment to the original condition of trouble. Figure 6 shows, in the form of frequency distributions, exactly what had happened to Characteristic B. Distribution A was the universe in its normal state of control. The data consists of over a thousand individual readings. Distribution B is the special data collected during the investigation. Note the appearance of secondary modes in this latter distribution, and its considerably wider spread.

Now Characteristic B was the height of an assembly composed of several parts; so an investigation of the trimodality of its distribution naturally involved an investigation of its parts. Figure 7 shows three of its principal components at the time the trouble began. Part Y appears to be a normal distribution. Part Z probably indicates a mixture of several lots. But in the case of Part X there is a mixture which is particularly evident, and the individual distributions are widely spread. All of the measured values for Part X were within the limits specified; but because of the correspondence between its widely separated modes and the unwanted modes which had appeared in the distribution of assemblies (Figure 6), it was decided to investigate the effect of variations in Part X on Characteristic B.

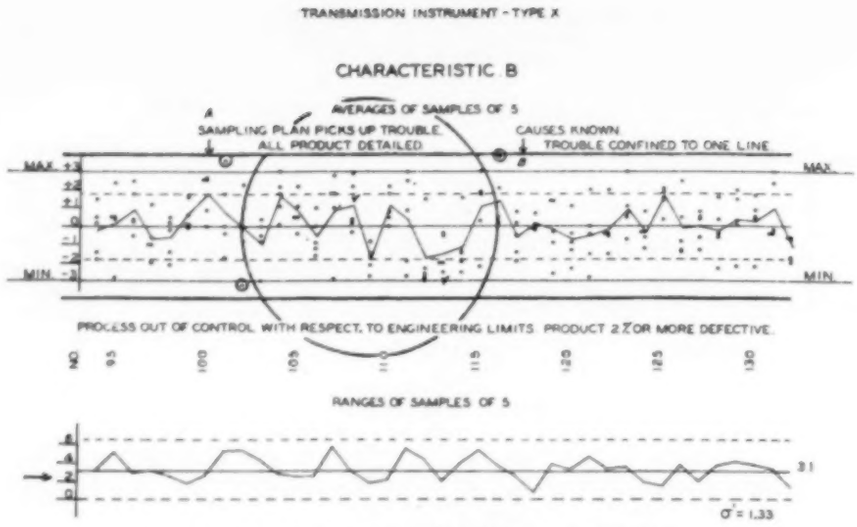


FIGURE 5 — THE SHOP'S PROTECTIVE CONTROLS

Figure 8 shows what such an investigation found. When mixed lots of Part X were fed into the line the resulting assemblies were plainly uncontrolled. When a uniform lot of Part X was substituted at point A, conformance and control were promptly restored. The arrow at point B marks a sudden deliberate change from a uniform maximum to a uniform minimum lot. The assemblies felt the impact of the change, and the Shop quickly adjusted its assembling techniques to meet the new situation. But when these same maximum and minimum parts were supplied in mixed proportions, the Shop had no consistent basis for adjustment. In fact, when it attempted to make adjustments, based on temporary runs of parts that were either high or low, it introduced additional variability into the process, over and above what the parts would have contributed themselves.

It was therefore recommended that lots of Part X should be segregated at the machine, and their identity maintained through the plating and storing operations until they reached the assembly line.

ADDITIONAL KNOWLEDGE

The use of uniform parts uncovered another source of variation. The assembly fixtures used to hold the parts —some 120 of which were in use on the various lines—were found to have an unsuspected effect on their assembled height. This is shown in Figure 8 by the triangles and squares which represent assemblies from two of the fixtures that

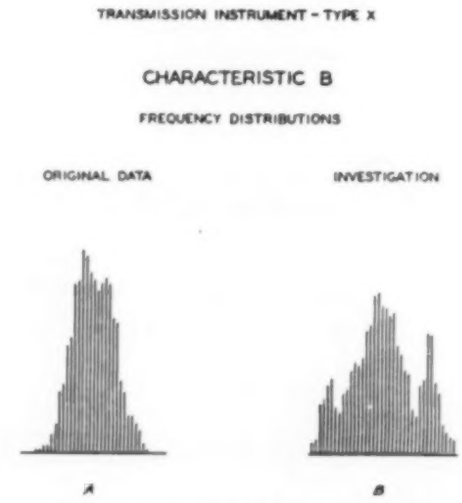


FIGURE 6 — DISTRIBUTION OF ASSEMBLIES

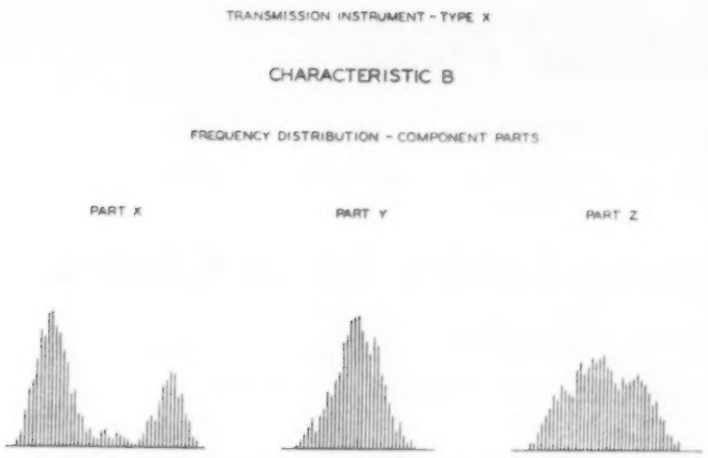


FIGURE 7 — DISTRIBUTION OF COMPONENT PARTS

were studied. With mixed parts, prior to Point A, either of the fixtures might produce assemblies of various heights. But with uniform parts, between points A and C, all the triangles are consistently higher than the squares. A little study revealed which property of the fixtures was associated with this height, and limits were added to a drawing to ensure their uniformity.

The case of Characteristic B illustrates a second important function of an engineering audit. Just as in the case of Characteristic A, all of the Shop's normal controls were functioning in the proper manner. They had held Part X within its specified limits. There was nothing about the assembly fixtures which violated any existing requirement. When the trouble became evident in product, the Shop took the necessary steps to control the outgoing product. But the chart showed that there was still need of engineering action on the process. It guided investigations which, in turn, shed important light on a set of interlocking causes, reduced the cost of production, and made it possible to seal up loopholes which might have been a continuing source of periodic trouble. In other words, the control-chart study contributed directly to the engineering knowledge of the job.

In both of these examples the primary purpose of the audit was, of course, to determine whether the finished product was in a state of satisfactory control. The other advantages which we have seen—detection of unsuspected quality deviations, additions to the fund of engineering knowledge, a powerful stimulus and aid to the achievement of control in cases where it is threatened or has never quite been reached — all these are natural by-products resulting from the analysis of engineering data by means of control-chart techniques.

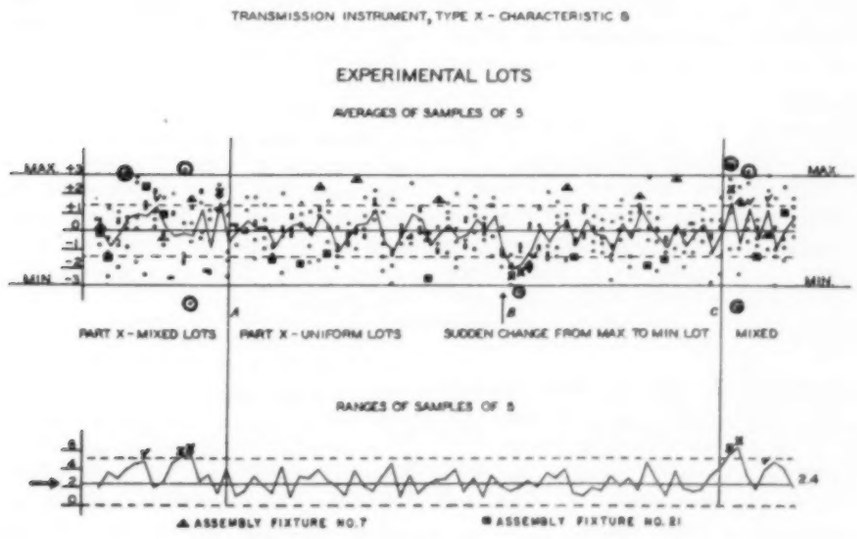


FIGURE 8 — EFFECT OF MIXED LOTS

REFERENCES AND NOTES

PART 1.

(1) W. A. Shewhart, "Economic Control of Quality of Manufactured Product," D. Van Nostrand Co., Inc., New York (1931).

(2) A.S.A. War Standard Z 1.3, "Control Chart Method of Controlling Quality during Production," Am. Stds. Assn., New York (1942).

(3) H. F. Dodge and H. G. Romig, "Sampling Inspection Tables," John Wiley and Sons, Inc., New York (1944).

(4) This type of chart is customarily referred to as a conformance-control chart in Bell System quality control work. When process variability (6σ) is smaller than the specified tolerance, the conformance-control limits (dotted lines) are usually placed inside the specified limits by an amount equal to $3\sigma - 3\sigma/\sqrt{n}$; and "product limits" (solid lines), representing acceptable levels for the product average, are placed inside the specified limits by an amount equal to 3σ. The dotted lines are similar to the "modified" control limits given by E. H. Sealy, "A First Guide to Quality Control for Engineers," Ministry of Supply, Advisory Service on Quality Control, C. P. R. S. D. (S.R. 17), London (Sept. 1943), except that the latter are placed inside the specified limits by an amount equal to $3.09\sigma - 1.96\sigma/\sqrt{n}$. When 6σ is equal to or greater than the specified tolerance, Bell System conformance-control limits are placed $3\sigma/\sqrt{n}$ on either side of the engineering mean.

(5) Simple non-parametric tests, and tests for unlikely extreme runs, are based on considerations similar to those discussed by E. L. Grant, "Statistical Quality Control," McGraw-Hill Book Co., Inc., New York and London (1946).

Editor's Note: Part 2 of Miss Small's paper will appear in the September 1949 issue of IQC.

Practical Aids

ELLIS R. OTT, Editor

Aids for Computing Limits for p Charts

JOHN M. HOWELL

DEPARTMENT OF MATHEMATICS, LOS ANGELES CITY COLLEGE

Some of the most annoying calculations in elementary quality control are those involved in finding control limits for p and np charts. A number of methods have been used to simplify these calculations. The simplification described here makes use of logarithmic charts. Since the distance from the central line ($\bar{p}$) to the upper control limit varies inversely as the square root of the sample size for given fraction defective, it may therefore be represented by a straight line on logarithmic paper.* By choice of suitable logarithmic paper, a chart may be made for any desired combination of sample size and average fraction defective.

Table 1 gives values of $\sigma_p\sqrt{n}$ and $\sigma_p\sqrt{n/10}$. These two columns provide an easy method of determining values corresponding to any other sample size not shown in the table provided the sample size can be obtained from the values of n in the table by shifting the decimal point. Other columns are given in Table 1 so that $3\sigma_p$ can be found in the same way.

In order to draw a chart such as Figure 1 or 2, find from Table 1, values of σ_p (or $3\sigma_p$) corresponding to two different sample sizes which are different powers of 10 (such as in columns 3 and 4 for $n = 100$ and $n = 1000$) for some particular desired average fraction defective. Locate these two points on the chart and connect them with a straight line. Then, corresponding to different choices of p, as many other lines as desired can be drawn to complete the chart. For example, to draw the 3% line in Figure 1, we find that $\sigma_p\sqrt{n} = .1706$; then $\sigma_p = .01706$ or 1.706% when $n = 100$, and $\sigma_p = 5.394\%$ when $n = 1000$.

* $(\sigma_p = \sqrt{\bar{p}(1-\bar{p})}/\sqrt{n})$

This new department in IQC will be a regular feature if contributors support it. Write up and send your "Practical Aid" to
Dr. Ellis R. Ott, Rutgers University
77 Hamilton Street
New Brunswick, N. J.

The upper 3σ control limit for a p chart is obtained by adding $3\sigma_p$, found on the chart, to the average fraction defective $\bar{p}$. If it is desired to have a dotted line on the graph to indicate when the lower control limit is zero, find the point on each diagonal line for which $\bar{p} - 3\sigma_p = 0$, and connect these points. This will be a straight line, or very nearly so for most values used.

The upper 3σ control limit for a p chart is obtained by adding $3\sigma_p$, found on the chart, to the average fraction defective, $\bar{p}$. The lower 3σ control limit is found by subtracting $3\sigma_p$ from $\bar{p}$ if the point lies to the right of the dotted line on the chart. If the point lies to the left of the dotted line, the lower limit is zero.

Example 1. Find 3σ limits for a p chart if $\bar{p} = 2.5\%$ and $n = 235$.

Enter bottom of chart in Figure 1 with $n = 235$, go vertically to diagonal line for $\bar{p} = 2.5\%$, go horizontally to right and read $3\sigma_p = 3.06$. Then UCL $= 2.5 + 3.06 = 5.56\%$. LCL $= 0$ since point in table is to left of dotted line.

Example 2. Find 3σ limits for a p chart if $\bar{p} = 4.5\%$ and $n = 1200$.

Enter bottom of Figure 1 with $n = 1200$, go vertically to line for $\bar{p} = 4.5\%$, go horizontally to right and read $3\sigma_p = 1.8\%$. Then

UCL $= 4.5 + 1.8 = 6.3\%$;
LCL $= 4.5 - 1.8 = 2.7\%$.

Example 3. Find 2σ limits for np chart if $\bar{p} = 6\%$ and $n = 700$.

Enter bottom of chart at $n = 700$, go vertically to line for $\bar{p} = 6\%$, go horizontally to left and read $\sigma_p = 0.9\%$. Then UCL $= 700[6 + 2(0.9)]/100 = 54.6$;
LCL $= 700[6 - 2(0.9)]/100 = 29.4$.

Values of σ_p are shown on the left side scale in both Figure 1 and 2. Values of $3\sigma_p$ can be read by referring to the scale on the right in these same Figures since it is prepared from the left scale by direct multiplication.

Note 1. Some previous tables and charts of this general type have not limited sample sizes with relation to the average fraction defective. This has resulted in values in the tables, which, if used, would give a control chart with an upper limit 20 or 30 times as far from the central line as from the lower limit, when the lower limit is zero. Such a control chart would appear somewhat ridiculous and be of little use, even though it is technically correct. The last column in Table 1 gives minimum values of sample size so that the upper control limit is not more than twice as far from the central line as is the lower control limit, when the lower limit is zero.

Note 2. To establish a minimum sample size so that the upper limit is not more than twice as far from the central line as the lower limit, when the lower limit is zero, we take: $\text{UCL} - \bar{p} = 3\sqrt{\bar{p}(1-\bar{p})} \leqslant 2\bar{p}$. Solving for n gives:

$n \geqslant 9(1-\bar{p})/(4\bar{p}) = 2.25(1-\bar{p})/\bar{p}$.

Values of n that satisfy this relation for assigned values of $\bar{p}$ are shown in the last column on the right in Table 1. For example, if the average percent defective is 4.5%, we find from Table 1 that the smallest sample size that will have an upper control limit not more than twice as far from the central line as the lower control limit, is 48.

TABLE 1

$\bar{p}$	$\bar{p}(1-\bar{p})$	$\frac{\sigma_p\sqrt{n}}{=\sqrt{\bar{p}(1-\bar{p})}}$	$\sigma_p\sqrt{n}/\sqrt{10}$	$3\sigma_p\sqrt{n}$	$3\sigma_p\sqrt{n}/\sqrt{10}$	$\frac{2.25(1-\bar{p})}{\bar{p}}$
.001	.000999	.031606961	.009994999	.094820883	.029984997	2248
.002	.001996	.044676616	.014127986	.134029848	.042383958	1123
.003	.002991	.054690036	.017294508	.164070108	.051883524	748
.004	.003984	.063118935	.019959960	.189356805	.059879880	561
.005	.004975	.070533680	.022304708	.211601040	.066914124	448
.006	.005964	.077226938	.024421302	.231680814	.073263906	373
.007	.006951	.083372657	.026364749	.250117971	.079094247	320
.008	.007936	.089084230	.028170907	.267252690	.084512721	279
.009	.008919	.094440457	.029864695	.283321371	.089594085	248
.010	.009900	.099498744	.031464266	.298496232	.094392798	223
.0125	.01234375	.111102430	.035133673	.333307290	.105401019	178
.015	.014775	.121552458	.038438262	.364657374	.115314786	148
.0175	.01719375	.131124940	.041465347	.393374820	.124396041	127
.020	.019600	.140000000	.044271887	.420000000	.132815661	111
.025	.024375	.156124950	.049371044	.468374850	.148113132	88
.030	.029100	.170587221	.053944416	.511761663	.161833248	73
.035	.033775	.183779759	.058116263	.551339277	.174348789	63
.040	.038400	.195959179	.061967733	.587877537	.185903199	54
.045	.042975	.207304124	.065555320	.621912372	.196665960	48
.050	.047500	.217944947	.068920244	.653834841	.206760732	43
.060	.056400	.237486842	.075099934	.712460526	.225299802	36
.070	.065100	.255147016	.080684571	.765441048	.242053713	30
.080	.073600	.271293199	.085790442	.813879597	.257371326	26
.090	.081900	.286181760	.090498619	.858545280	.271495857	23
.100	.090000	.300000000	.094868330	.900000000	.284604990	21
.110	.097900	.312889757	.098944429	.938669271	.296833287	19
.120	.105600	.324961536	.102761861	.974884608	.308285583	17
.130	.113100	.336303434	.106348484	1.008910302	.319045452	16
.140	.120400	.346987031	.109726934	1.040961093	.329180802	14
.150	.127500	.357071421	.112915898	1.071214263	.338747694	13
.200	.160000	.400000000	.126491106	1.200000000	.379473318	9
.250	.187500	.433012702	.136930639	1.299038106	.410791917	7
.300	.210000	.458257569	.144913767	1.374772707	.434741301	6
.400	.240000	.489897949	.154919334	1.469693847	.464758002	-
.500	.250000	.500000000	.158113883	1.500000000	.474341649	-

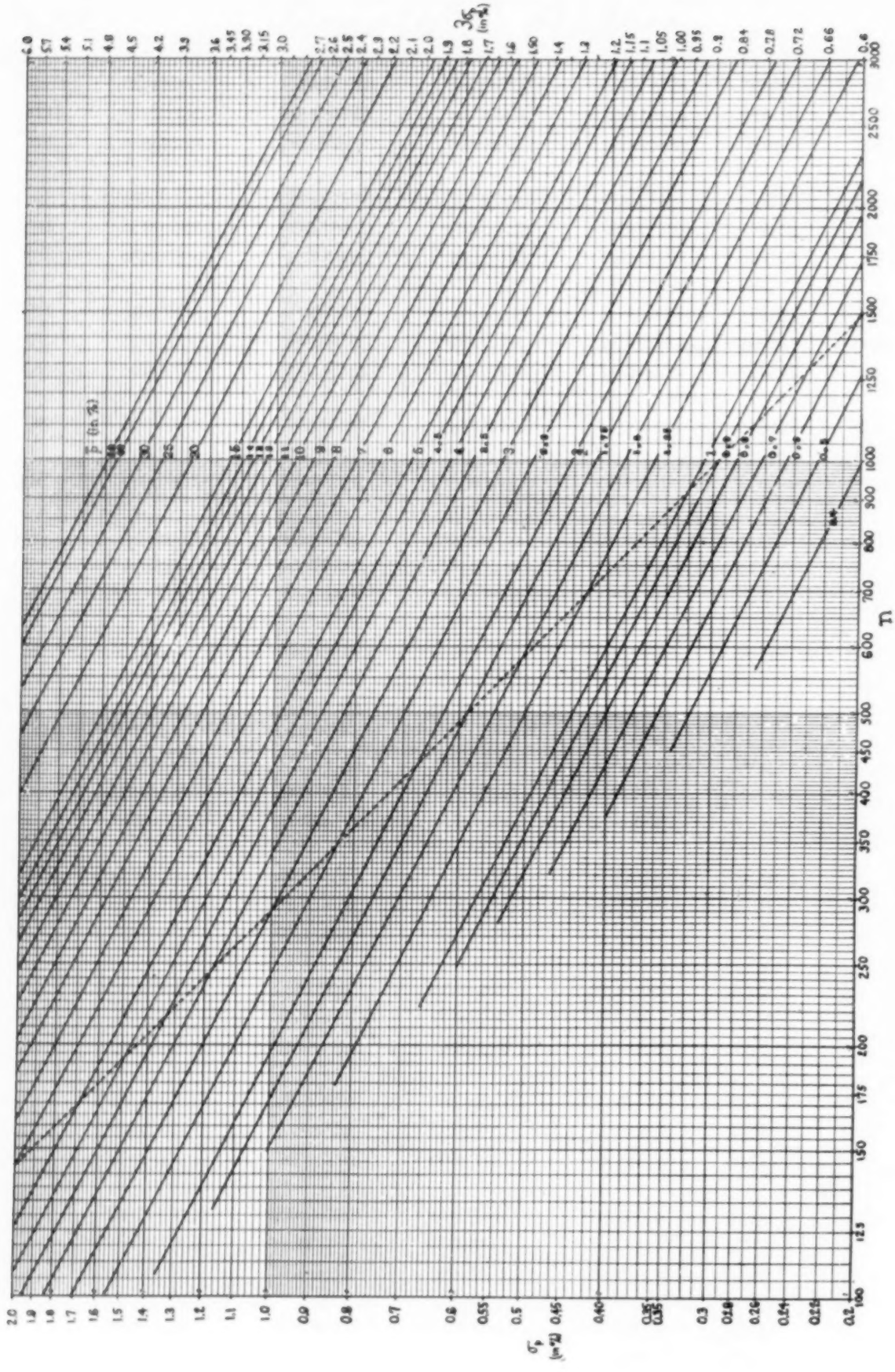


FIGURE 1 — NOMOGRAPH FOR p CHART CONTROL LIMITS

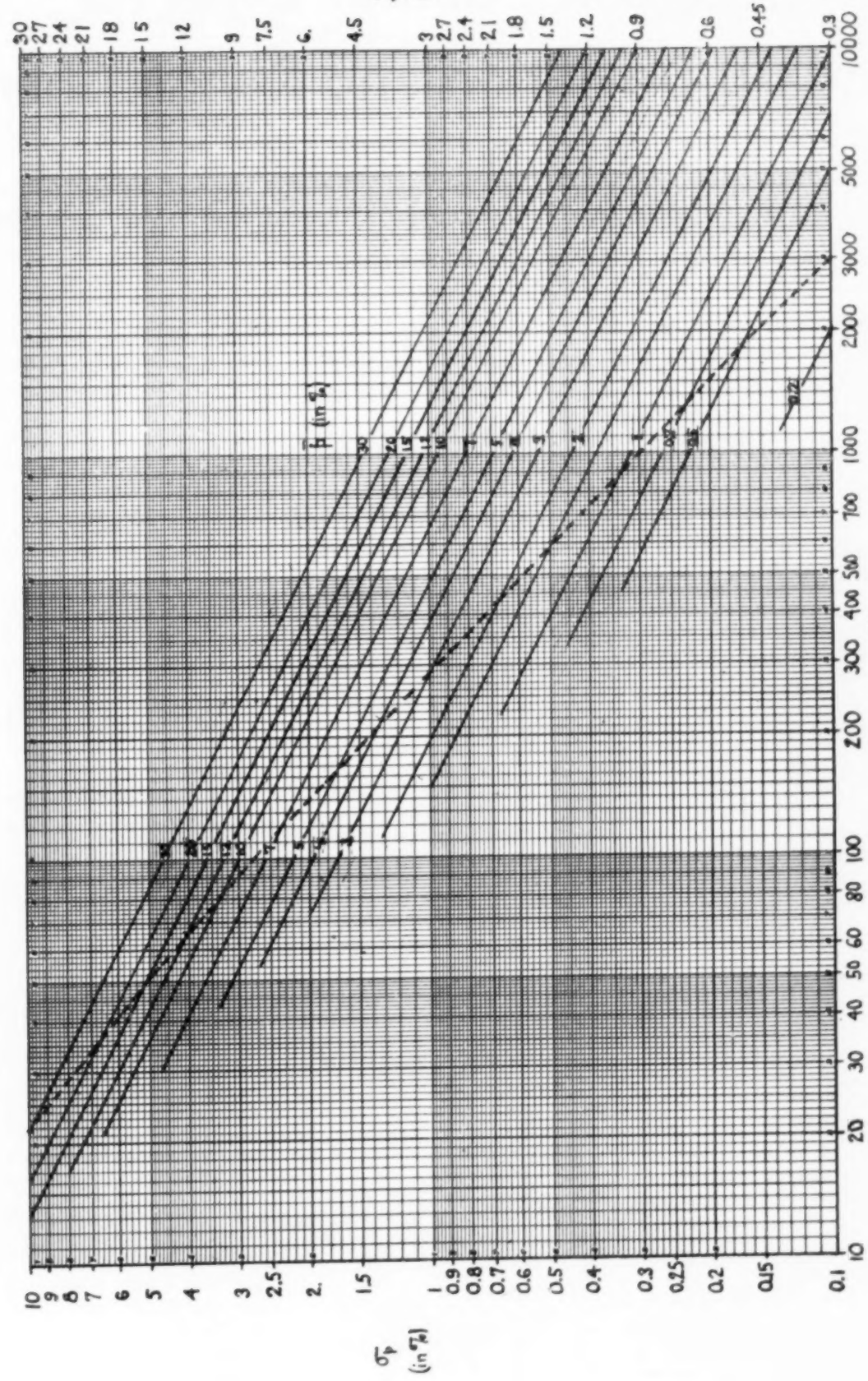


FIGURE 2 — NOMOGRAPH FOR p CHART CONTROL LIMITS

Probability Center Lines for Standard Deviation and Range Charts†

CHURCHILL EISENHART

CHIEF, STATISTICAL ENGINEERING LABORATORY, NATIONAL BUREAU OF STANDARDS, WASHINGTON, D. C.

"No analysis, however careful, will enable a change in conditions to be detected before it has begun to occur; but precise methods have often provided data from which the experienced investigator recognizes the first signs of a change some time before this could be discovered by cruder methods . . ."

*—E. S. Pearson [5]**

PROBABILITY-CENTERED CENTRAL LINES

There is much to be gained by having the central lines on control charts centered - in - probability. With central lines centered-in-probability the statistical significance of the partition of the observed points into "above" and "below" can be tested simply by reference to published significance levels of the **sign test** [2] based on the binomial distribution for $p = 1/2$; and runs above and below the central line can be compared with run theory for Bernoulli trials with $p = 1/2$ [7]. These procedures are already regarded as important accessories [4, 7] of control charts for averages, $\bar{X}$, the central lines of which are centered-in-probability. It is the object of this note to make these procedures available for use with σ- and R-charts also, by providing the factors needed to obtain probability center lines for these charts. These factors, h and H, are given by Table 1.

If it is tenable to assume that the process is in a state of statistical control with respect to variability (i. e. with respect to σ or R), but there is some doubt regarding the exact value of the process standard deviation, σ′, then, as will be shown in an example below, the above factors can be used in conjunction with significance levels of the sign test [2] and a table of the values of c_2 and d_2 [1], to obtain rough confidence limits for the unknown value of σ′.

TABLE 1

Sample Size, n	Factor (h) by which to reduce $c_2\sigma'$ or $\bar{\sigma}$	Factor (H) by which to reduce $d_2\sigma'$ or $\bar{R}$
2	.8453	.8453
3	.9394	.9382
4	.9639	.9608
5	.9746	.9704
6	.9804	.9754
7	.9841	.9781
8	.9866	.9803
9	.9885	.9818
10	.9899	.9826
12	.9918	.9842
15	.9937	.9856
20	.9954	.9869
24	.9962	
30	.9971	

ILLUSTRATIVE EXAMPLES

In connection with another study, Dr. W. J. Youden utilized a sequence of 400 samples of 3 observations each drawn at random from a normal population with zero mean and unit standard deviation. He kindly made these available to me, and the first 50 ranges are listed here, reading in order from left to right by rows.

0.96, 2.69, 1.27, 1.65, 2.45,
0.79, 2.24, 1.75, 2.29, 1.93,
1.83, 1.76, 0.45, 0.80, 0.78,
0.79, 1.17, 0.85, 1.15, 1.14,
2.00, 0.73, 2.32, 2.05, 1.32,
1.32, 0.40, 1.44, 1.23, 0.66,
1.64, 0.74, 0.92, 0.83, 1.65,
1.82, 4.09, 1.56, 2.82, 0.96,
0.52, 1.06, 0.47, 1.66, 1.47,
0.54, 2.18, 1.05, 2.04, 1.57.

This sequence is shown in Figure 1. Since a standard is given, that is, $\sigma' = 1$, the upper and lower (3-sigma) control limits are given by $D_1\sigma'$ and $D_2\sigma'$, which for $n = 3$ are 0 and 4.358, respectively. It is evident that these data are in statistical control according to the traditional procedure.

Example 1: Construct the probability-center line for these data.

Solution. The 0.50-probability center line for these data is determined by $Hd_2\sigma'$, which for $n = 3$ and $\sigma' = 1$ equals (0.9382) (1.693) (1) = 1.588. This line is shown as the central line in Figure 1.*

* Numbers in [ ] refer to the list of references at the end.

† Presented at the 4th Middle Atlantic Regional Meeting of the American Society for Quality Control held jointly with the Central New Jersey Chapter of the American Statistical Association, in Princeton, N. J., 3-4 December 1948.

* For comparison the conventional line through $d_2\sigma' = 1.693$ is indicated by short marks on the vertical scales.

Example 2: Test the above data for statistical control with respect to the specified standard by the statistical sign test at the 0.05 level of significance.

Solution. A count reveals 20 points above the central line and 30 points below, a partition well within the significance levels of the sign test, which requires that the smaller of the two numbers be 17 or less for statistical significance at the 0.05 level when $n = 50$. (Out of curiosity one may count the number of points exceeding the classical central value, 1.693, finding a partition of 16 points above and 34 below, which would be statistically significant at the 0.05 level. Alternatively stated, had we assumed $\sigma' = 1.07$, that is, the reciprocal of 0.9382, we would have been led to suspect this assumption.)

Example 3: Assuming control, with respect to what range of values of σ' are the observed data consistent?

Solution. The 17th value in order of size counting from the bottom is 0.96; counting from the top, 1.66. Dividing each by 1.588, from Example 1, we obtain 0.60 and 1.05 as the upper and lower end points of an open confidence interval for σ' at the 0.95 level of confidence. That is, **if the data are in control,** then we are 95% sure that $0.60 < \sigma' < 1.05$.

DISCUSSION

Control charts for standard deviations, σ, or for ranges, R, are today standard tools of statistical quality control. How many persons have noticed the slight but definite tendency for **more points** to lie **below** than above the central line of these charts when the process is judged to be in a state of statistical control? I know of at least one plant where such a tendency was noted by the men on the production line. In this case the quality control engineer felt obliged to explain that it did not necessarily signify a disposition of the production-line personnel to do a better-than-asked-for job more often than a worse-than-asked-for one.

The fact of the matter is that a tendency for more points to lie below than above the central line on a σ- or an R-chart is a property of the standard method of determining the central lines of such charts. These central lines are determined [1] so as to coincide with the **average** value of σ or R for the sample size (n) concerned in repeated random sampling from a stable normal population. Owing to the positive skewness of the distributions of σ and R in random samples from a normal population, values less than the **average** ($c_2\sigma'$ for σ, $d_2\sigma'$ for R, where σ' is the population standard deviation) have a probability of occurrence slightly in excess of one-half. Table 2, based on [3], gives values of some of these probabilities.

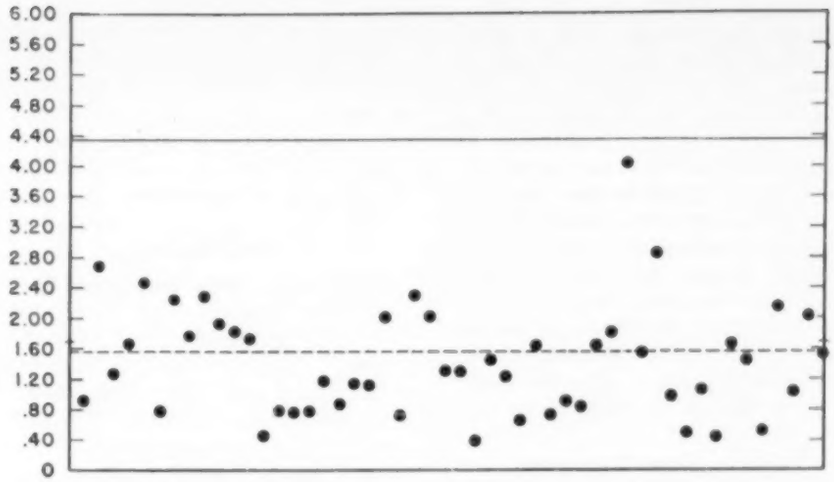


FIGURE 1 — CONTROL CHART FOR RANGES IN FIFTY SAMPLES OF THREE

Anyone who feels that these probabilities are so close to one-half that the differences are quite unimportant will do well to recall that differences of this order of magnitude played an important role in the early stages of the development of the mathematical theory of probability: **1.** Galileo (1564-1642) was consulted by an Italian nobleman for an explanation of the following: whereas, when three dice are thrown, 10 points and 9 points can each be obtained in six different "ways," it is found from actual experience that 10 is thrown more often than 9. Galileo made a careful and accurate analysis and showed that out of 216 possible cases 27 are favorable to 10 ($p = 0.125$) and 25 are favorable to 9 ($p = 0.116$). **2.** A decade after Galileo's death, Chevalier de Méré, a French gentleman with mathematical interests and considerable experience at dice, pressed Pascal (1623-1662) for advice on various gambling matters. Of interest to us here is his request for an explanation of why he was losing money through betting that double sixes would be thrown at least once in twenty-four throws of a pair of dice.

TABLE 2

Sample Size, n	Probability of an observed σ being less than $c_2\sigma'$	Probability of an observed R being less than $d_2\sigma'$
2	.575	.575
3	.544	.545
4	.531	.536
5	.527	.531
6	.524	.529
7	.521	.528
8	.519	.527
9	.518	.527
10	.517	.527
12	.515	.5265
15	.513	.527
20	.511	.527
24	.510	
30	.509	

His analysis showed this to be a "safe" bet (i. e. p greater than ½). Pascal, in a letter to Fermat dated 29 July 1654, gave his analysis of the situation: it is **not** a safe bet—the probability of **losing** is 0.509. Not very large differences these (0.009 in each instance), but large enough to be sensed by and to concern experienced gamblers! What is more, present day gamblers who know their business systemmatically take advantage of differences just as small [6], betting, for example, against the shooter in "craps," since **his** probability of **losing** is 1004/1980=0.507.

CONCLUDING REMARKS

These "probability center lines" for σ- and R-charts are by-products of certain investigations being carried out at the Statistical Engineering Laboratory, National Bureau of Standards, under the direction of the present author. These new lines have been tried out on "textbook examples" found in various standard textbooks, with pleasing success. However, since the author is not on the "statistical quality control firing line," so to speak, he has not been able to give them a full test of experience. He sincerely hopes that others will give them a trial in their routine work, and will report to him any difficulties found in their application, as well as any "successes" that may honestly be attributed to them. In practical matters of this sort, "the proof of the pudding is in the eating" and there is no substitute for the acid test of experience.

REFERENCES

[1] **American War Standard** Z1.3—1942, "Control Chart Method of Controlling Quality During Production," American Standards Association, New York, 1942. (The authoritative, concise statement of American control-chart practices.)

[2] W. J. Dixon and A. M. Mood, "The Statistical Sign Test" **Journal of the American Statistical Association,** Vol. 41 (1946), 557-566.

[3] Churchill Eisenhart and Celia S. Martin, "The Relative Frequencies with which Certain Estimators of the Standard Deviation of a Normal Population Tend to Underestimate its Value." Abstract and basic table distributed at meeting of the Institute of Mathematical Statistics, Madison Wisconsin, 7 September 1948. Abstract published in **Annals of Mathematical Statistics,** Vol. 19 (1948), p. 600.

[4] Paul S. Olmstead, "How to Detect the Type of an Assignable Cause." Presented at the Third Midwest Quality Control Conference, held in Chicago, 4-5 November 1948; and at the 108th Annual meeting of the American Statistical Association, held in Cleveland, Ohio, 27-29 December 1948.

[5] E. S. Pearson, "The Application of Statistical Methods to Industrial Standardization and Quality Control," British Standard 600l: 1935, British Standards Institution, London. The quotation is from page 27.

[6] John Scarne and Clayton Rawson, **Scarne on Dice,** The Military Service Publishing Company, Harrisburg, Pa., 1945. A book on dice games and gambling, but well worth reading by anyone who wants to get a practical "feel" for probability.

[7] Walter A. Shewhart, "Contribution of Statistics to the Science of Engineering," published on pp. 97-124 of book entitled **University of Pennsylvania Bicentennial Conference. Volume on Fluid Mechanics and Statistical Methods in Engineering,** 1941. Available also as Bell Telephone System Monograph B-1319.

Checking Process Spread Against Specification Limits for a Process Operating in Tight Control

EDWARD S. SMITH

DEPARTMENT OF MATHEMATICS, UNIVERSITY OF CINCINNATI

In making a control chart in an application of statistical quality control, a matter of primary importance, after getting the process under control, is to determine whether or not the control is satisfactory. The usual procedure is given in "Control Chart Method of Controlling Quality During Production," the American War Standard Z 1.3, 1942. In this procedure standard values of $\bar{X}'$ for average value, and σ' for measuring the spread of individual items about the average, are adopted. These values are accepted as satisfactory if the band $\bar{X}' \pm 3\sigma'$ falls within the band defined by specification limits, that is, within X-Min and X-Max.

It seems to the writer that there is lack of clarity in the procedure as outlined above because of the failure to indicate whether or not the maximum and minimum values given in the specifications are acceptable values. The specifications should always make two things clear: first, whether or not the measurements are to be rounded off to

the unit indicated in the limits, and second, whether or not the specified limits (including a dimension that rounded off would correspond to one of the specified limits) represent acceptable values. In this article it will be shown that if these are acceptable values then the band $\bar{X}' \pm 3\sigma'$ may contain the band X-Min to X-Max of specifications.

Let us use an example from the point of view of the inspector for developing our thesis. Suppose that for a machined part the specifications call for a diameter of 0.750 inch ± 0.003 inch. Then for the inspector it should be clearly indicated whether a dimension X is to be measured and rounded off to thousandths of an inch or is to be recorded to ten-thousandths or smaller units, and also whether or not dimensions of 0.747" and 0.753" are acceptable. If measured and recorded to thousandths of an inch, then such measurements as 0.7526" or 0.7534" would be recorded as 0.753" and specifications should clearly indicate whether or not, if 0.753" is acceptable 0.7534" is also, or whether no piece would be acceptable which measured the least amount above 0.753" or below 0.747."

We shall establish the relationship between specification limits and control limits under the assumption that acceptable values will include end values given under specifications, and also all values that would round off to these end values. Thus for the example cited of the machined part, the inspector's list of acceptable values would be

(1) 0.747, 0.748, 0.749, 0.750
0.751, 0.752, 0.753,

and pieces for which the measurement X fell in $0.7465 < X < 0.7470$ and $0.7530 < X < 0.7535$ would be acceptable pieces.

We should note that for the example cited if no measurement is acceptable that is less than 0.7470, or greater than 0.7530, by however small an amount, then parts with dimensions of 0.7470 and 0.7530 are so dangerously near being unacceptable that strenuous efforts would be made to avoid having any parts produced with these dimensions. Under the assumption of the preceding paragraph, this would be equivalent to saying that acceptable end values should in this case be 0.748 and 0.752. This would of course require a σ' that would draw the control limits in so that they should fall within the band 0.7470 to 0.7530. The condition stated here for the example would apply in general.

If the manufacturing process (of the example) is in satisfactory statistical control, and if parts are taken at random from the production stream and measured to thousandths of an inch, the dimensions so recorded should range among the values given in (1). These measurements would form a discrete set of values that should be expected to have a nearly normal distribution. The theoretical distribution of successes in coin tossing would therefore serve as a model to idealize the situation we are studying, and hence to determine ideal control limits and maximum natural tolerance for these machined parts.

In tossing coins the theoretical frequency of occurrence of the various number of heads that may come up in N tosses of n coins each, is given by the terms in the binomial expansion of $N(q+p)^n$, with $p=q=\frac{1}{2}$, (where p and q represent the probability of success and failure, respectively). For such a distribution we have*

$$(2) \qquad \sigma' = \sqrt{npq} = \sqrt{n(\tfrac{1}{2})(\tfrac{1}{2})} = \tfrac{1}{2}\sqrt{n}.$$

Thus, if $N = 256$ and $n = 6$, we may use the sequence

(3) −3, −2, −1, 0, 1, 2, 3

to denote 0, 1, 2, 3, 4, 5, and 6 heads, respectively, in any toss. The theoretical frequency distribution for the 256 tosses would be given by the terms in the expansion

$$(4) \qquad 256(\tfrac{1}{2}+\tfrac{1}{2})^6 = 4+24+60+80+60+24+4.$$

From (4) it is seen that theoretically in 256 tosses of 6 coins there would be 4 cases in which there would be no heads, 24 with 1 head, 60 with 2 heads, etc.

By (2) we find that for this distribution

$$(5) \quad \sigma' = \tfrac{1}{2}\sqrt{n} = \tfrac{1}{2}\sqrt{6} = \tfrac{1}{2}(2.44949) = 1.225 \text{ (to 3 decimals).}$$

The 6σ spread, or "natural tolerance" for this distribution is therefore,

$$(6) \qquad 6\sigma' = 7.350,$$

* See Elmer B. Mode "Elements of Statistics," Prentice Hall, pp. 328-329.

and this is greater than the spread of 6 from 0 heads to 6 heads, or the spread of 7 on a continuous scale from—3.5 to 3.5. In either case, the three-sigma limits fall outside of end values.

By following common practice we can use the sequence (3) to represent the sequence (1) by taking 0.750 as 0, and the other entries as ±1, ±2, ±3, with —3 corresponding to 0.747, and +3 to 0.753. Then, under the assumption in the paragraph containing (1), the discrete set obtained from the measurements of the machined parts are analogous to the set that represents the number of heads that come up in tossing coins, except that dimensions **recorded** as 0.747 may actually be somewhere **between** 0.7465 and 0.7475, i. e., between —3.5 and —2.5, and pieces **recorded** as 0.753 may actually be somewhere **between** 0.7525 and 0.7535, i. e., between 2.5 and 3.5. The number n in tossing coins is the number of coins tossed and in any case is one less than the number of entries in a sequence such as that in (3). Similarly, the number n here is the number of subdivisions used on the instrument for measuring diameters, and is one less than the number of acceptable measurements that may be recorded, such as in the sequence (1).

Let us now determine those values of n for which the 6σ spread will fall inside or outside of specification limits. But first it should be noted that we are concerned with the maximum allowable sigma as determined by (2). In practice σ' is usually found by using $\bar{R}$, and the value of σ' so determined is very often much smaller than would be found by $\frac{1}{2}\sqrt{n}$. While the recorded dimension X ranges among the discrete sequence shown in (1) or (3), the actual dimension X may have any value on the range $0.7465 < X < 0.7535$. Hence we should consider the histogram tor (4), as applied to our example, as resulting from a continuous set of values extending from —0.5 to 6.5, or corresponding to a spread of 7. Thus under the conditions of our example the inspector records dimensions over n unit intervals but there will be n+1 intervals over which the actual dimensions can range. Then the maximum σ' which we can tolerate will be $\frac{1}{2}\sqrt{n}$ and n must satisfy the inequality

$$(7) \qquad (n+1) \geq 6(\tfrac{1}{2}\sqrt{n}).$$

From (7) we find that $n \geq 6.85$, and as n

must be an integer we see that 7 is the smallest value of n that will put 3-sigma limits within the (n+1) unit range which the convention permits. For n=6 the 6-sigma range extends beyond the (n+1) unit interval by an amount less than will be observable on the measuring instrument. For n<6 the 6-sigma spread will extend too far over the (n+1) unit interval for any practical usefulness.

It should be observed that in many applications n is 6, and we have just seen that for this value of n the 3-sigma limits are outside of specifications by such a small amount that they may be considered as acceptable. We should be careful to avoid using n less than 6.

We shall now extend our example to show the relationship between specification limits and three-sigma limits (under our assumption) for the case n=6, and N=256. The theoretical distribution of 256 items from the sequence (3), or (1), corresponding to the machined parts, is given in Table 1.

The value of σ' for the individual items of Table 1 may be computed by the use of the simplified formula

(8) $$\sigma' = \sqrt{\Sigma X^2/N - (\bar{X})^2}.$$

The computations may be made by using Table 2, the entries in which should be obvious and readily checked. From this table we see that

(9) $$\bar{X}' = 0$$

and

(10) $$\sigma' = \sqrt{384/256} = \tfrac{1}{2}\sqrt{6} = 1.225 \text{ (to 3 decimals)}$$

in agreement with the value of σ' found in (5).

The values in (9) and (10) can be interpreted in terms of the actual dimensions of the machined parts. Thus from (9) the average value $\bar{X}'$ is

(11) $$\bar{X}' = 0.750.$$

Using (11) and (10) we find the three-sigma limits are

(12) $$\bar{X}' \pm 3\sigma' = 0.750 \pm 0.0037 = 0.7463 \text{ to } 0.7537.$$

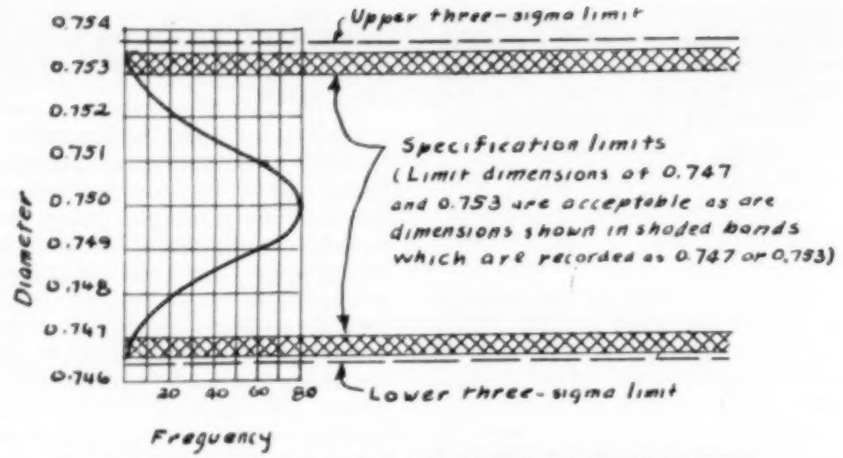


FIGURE 1 — DISTRIBUTION DIAGRAM FOR DATA OF TABLE 1

TABLE 1—THEORETICAL DISTRIBUTION OF 256 PARTS

Diameter X	Frequency f
3 (0.753)	4
2 (0.752)	24
1 (0.751)	60
0 (0.750)	80
—1 (0.749)	60
—2 (0.748)	24
—3 (0.747)	4

TABLE 2—COMPUTATIONS FROM WHICH TO OBTAIN SIGMA

X	f	fX	fX^2
3	4	12	36
2	24	48	96
1	60	60	60
0	80	0	0
—1	60	—60	60
—2	24	—48	96
—3	4	—12	36
	256	0	384

The relationship between the specification limits and the three-sigma limits can be seen from the frequency curve shown in Figure 1.

In conclusion, it should be observed that the men in the production department are presumably trying to produce goods of high quality and that when they have brought a process under control the natural tolerance of the process may be much better than called for under specifications. In that case there are usually no end values made (or a negligible number of them) that may be allowed under specifications, and there may be a greater concentration about the central value than is normally to be expected. As a consequence, when sigma is computed from data obtained from such a production line the three-sigma limits may fall well inside of specification limits. However, this article is not intended so much for the man who is able to produce goods of better quality than that called for in specifications as it is for the man who is experiencing difficulty in meeting tight specification requirements. For him it should be gratifying to know that, if he is producing under tight control at the level of blue-print nominal, he may expect his three-sigma limits

(1) to be **within** blue-print tolerance if the number of subdivisions used in recording his data exceeds 6,

(2) to be beyond blue-print tolerance by an amount less than half a unit on his measuring instrument if the number of subdivisions used in recording his data **is** 6, and

(3) to be so far beyond blue-print tolerance when **fewer** than 6 subdivisions are used as to rule out the practical usefulness of measuring a dimension with fewer than 6 possible readings.

CONFERENCE PAPERS

$3.50 Postpaid

Alfred L. Davis, Treasurer, ASQC

65 Plymouth Avenue South

Rochester 8, N. Y.

ABSTRACTS OF CONVENTION PAPERS

Third Annual ASQC Convention

$1.50 Postpaid

Prof W. A. MacCrehan, New York University

New York 53, N. Y.

Guest Editorial--A.S.Q.C. Dues

GEORGE D. EDWARDS

The Officers of the American Society have received recently, from several members, formal or informal suggestions with respect to the desirability of constitutional changes which would result in levying equal dues upon all corporate members regardless of grade. That is, all would pay uniformly, say $8.00 or $8.50 per annum, instead of Members paying $5.00, Senior Members $10.00, and Fellows $15.00 as at present.

Had these suggestions come exclusively from relatively immature members, the Officers might properly have assumed that those making them were perhaps unacquainted with the financial problems of societies like ours and with the procedures which the major professional engineering societies have found most effective in meeting these problems successfully. One or two of the members in question were of indubitable maturity and experience however, and were highly esteemed Senior Members or Fellows of the Society.

Under these circumstances, the Officers felt justified in laying the suggestion before the Executive Committee, and the latter Committee felt called upon to give them its most careful consideration. After much discussion, the Executive Committee was unanimous in concluding that the present constitutional provisions for graduated dues are best adapted to the needs and advancement of ASQC from an overall point of view.

In reaching this conclusion however, the Executive Committee felt that the entire membership should be informed of the suggestions and of the Committee's reasons for reaching the conclusion which it had with regard to them. At the suggestion of the Chairman of the Editorial Board, the Executive Committee accordingly requested the writer, as Past President of the Society, to present an editorial with regard to the matter in Industrial Quality Control. This assignment is undertaken with some hesitancy, but with profound conviction of the wisdom of the Executive Committee's conclusion.

All of the suggestions mentioned were predicated upon stated objections to the principle of graduated dues. None of them met squarely, with constructive alternative suggestions, the question of how the Society might otherwise be financed. We must have money to meet the expenses of the Society, publish the magazine, etc. We must raise that money from our members in proportion, in degree at least, to their ability to pay. Otherwise, we will "freeze out" the younger men whom we want badly as members and who constitute our greatest potential source of candidates for the higher grades. Obviously, as our members grow in experience and ability, their income increases and their ability to pay increases. Our progressively higher dues for Senior Members and for Fellows recognize this.

It was objected that the graduated dues plan is used by few societies of real standing, and it was urged that ASQC should not stand out as an exception.

This objection is based either on an entire lack of knowledge of the facts or on a misconception of the kind of society which we are trying to build. ASQC is essentially a professional engineering organization, as distinguished from the many organizations of a more purely academic type, most of which are much smaller than ASQC must be if it is to survive. Neither are we a trade association with commercial rather than engineering objectives. ASQC organization is hence patterned after the essentially engineering societies such as the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, etc., whcih represent the oldest, the largest, and the most successful professional engineering organizations in the country. These societies adopted the graduated dues system for the same reasons that we have adopted it, and they have been using it successfully for years. If we were to adopt any other plan, we would stand out as an exception among societies of professional engineers.

It was urged that with the graduated dues system, election of a member to a higher grade could always be suspect,—that any need for more money might be met by elevation of unqualified members.

Certainly no Member or Fellow of ASME or AIEE is suspected of taint. Their Examining Committees are composed of engineers of the highest professional standing, and I am sure financial needs of these societies have never entered into election of individuals to their higher membership grades. Our Examining Committee is of equal standing, and I am sure it is equally free from such influences. It must always remain so.

To be sure, we have an escalator clause in our constitution which **permits acceptance of Senior Members of sub-professional qualifications until July 1, 1950.** This has enabled us to meet our financial problems during our early years. But after the date mentioned, our entire roster of Senior Members, old and new, will be of professional grade. There has been no such escalator provision with respect to Fellows, and this has been a strictly professional grade in ASQC from the start.

It has been objected that the higher dues of the upper grades impose an unfair hardship on professional members of limited income who wish to affiliate with a number of professional societies.

The graduated dues plan admittedly presents real difficulties for the man of limited income who has a tendency to be a "joiner." If he wishes to move into the higher grades in all of the major engineering societies, it obviously gets pretty expensive,—and intentionally so. A man is expected to select the field in which he proposes to become expert and definitely professional, and to aim for the highest grade in the corresponding society. He can obtain all of the privileges and advantages of as many other societies as he wishes at nominal cost by remaining in their lower grades, and he can scarcely expect to pose legitimately as a real expert in very many of these anyway.

Before adoption of our present system of graduated dues, it was the subject of many conferences and much discussion over several years. The several committees which studied the matter in detail were composed of able, mature, and experienced men who considered it from all angles and who made the

recommendations now incorporated in our constitution. These recommendations were approved by the Executive Committee and by the Board of Directors of the Society. Before ratification, the constitution was sent, in draft form, to every member of the Society, and the postal ballot adopting it showed 739 favorable ballots against 12 unfavorable. Since its adoption, the graduated dues plan has been working out with every success in ASQC, essentially as it was expected that it would, and essentially as it has worked out in the other major professional engineering societies. So long as we maintain a strictly professional and independent Examining Committee, experience has demonstrated that the plan cannot fail to continue successful.

Adoption of uniform dues for all grades of membership could only result in a falling off in our membership, and in almost insurmountable financial problems for the Society.

AMERICAN SOCIETY NEWS

ANNUAL MEETING — 1949

The Third Annual Meeting of the American Society for Quality Control was held in the Engineering Societies Building in New York City on Friday evening, 17 June 1949. At that meeting, the following officers were elected by the Society for the fiscal year 1949-50:

PRESIDENT:
Ralph E. Wareham
122 Orchard Ridge
Chappaqua, New York

VICE-PRESIDENT:
Wade R. Weaver
Director of Quality Control
Republic Steel Corporation
Cleveland, Ohio

EXECUTIVE SECRETARY:
Simon Collier
Director of Quality Control
Johns-Manville Corporation
New York, New York

TREASURER:
Alfred L. Davis
Associate Director—
Evening Extension Division
Rochester Institute of Technology
Rochester, New York

A complete report of the Annual Meeting, together with reports of the Board of Directors, Executive Secretary, and Treasurer will be presented in the September issue of Industrial Quality Control.

MEMBERSHIP ON THE BOARD OF DIRECTORS

The terms of the representatives of the following Sections on the Board of Directors expired on 30 June 1949:

Baltimore
Boston
California
Delaware
Hartford
Indiana
Metropolitan
Michigan
Mid-Hudson
Minnesota
New Hampshire
Ohio
Philadelphia
Rochester
South Texas
Southern Conn.
Syracuse
Western Mass.

In order that the new Board may be completed as early as possible, and particularly that the new Executive Committee may be constituted and begin functioning promptly, all of the above Sections which have not appointed Directors for the forthcoming term are urged to do so immediately and to notify the Executive Secretary of the names and addresses of their selections.

Present Directors are of course eligible to reappointment for succeeding terms where this is the wish of the Section concerned. Under the Constitution, present Directors will continue in office until their successors have been duly appointed and qualified.

MEMBERSHIP ON THE EXECUTIVE COMMITTEE

The terms of the Regional Directors for the New England, Northern, Middle Atlantic, Mid-West, and Western Regions expired on 30 June 1949. The Regional Director of the Central Region, Dr. Ralph A. Hefner, continues to serve for the 1949-50 Society year.

As soon as all Sections in each of the five Regions listed above have completed selection of their Directors, the Directors in each Region will choose a new Regional Director from among their own number.

In those cases where a Regional Director is reappointed as a Director to represent his Section, for the forthcoming term, he is of course again eligible for selection as Regional Director where this is the wish of the Directors concerned.

In order that the new Executive Committee may be constituted and become functioning as promptly as possible, all Sections in the above Regions having Directors whose term expired on 30 June 1949 are particularly urged to appoint their new Directors immediately and to notify the Executive Secretary of the names and addresses of their selections.

MORE STRINGENT QUALIFICATIONS FOR SENIOR MEMBERSHIP

Under the provisions of Section 4d. of the Constitution, the age and experience qualifications required of applicants for Senior Membership during the 1948-49 fiscal year have been age 25 and 3 years' experience, respectively.

Effective July 1, 1949, the Constitution requires that these age and experience qualifications be increased to age 26 and 4 years' experience. These new requirements will be in effect throughout the 1949-50 fiscal year, at the end of which a further similar increase will be made.

ASQC CONVENTION — 1950

The Fourth Annual Convention of the Society will be held in Milwaukee on June 1 and 2, 1950, under the joint sponsorship of the Mid-West Sections of the Society.

As the detailed plans for the meetings are worked out, announcement will be made of them in subsequent issues of Industrial Quality Control.

EXAMINING COMMITTEE

The Executive Committee of the Society has unanimously selected Dr. Lloyd A. Knowler of the Iowa Section as Chairman of the Examining Committee of the Society, effective as of 1 July 1949.

Dr. Knowler succeeds Dr. Paul S. Olmstead who asked to be relieved of the responsibilities as Chairman of the Committee but has agreed to serve for one additional year as a member of the Committee. Dr. Olmstead has served the Society faithfully and well as Chairman of the Examining Committee dur-

ing the first two years of the Committee's existence.

Also effective 1 July 1949, Dr. Walter A. Shewhart has resigned from the Examining Committee and Dr. Edwin G. Olds of the Pittsburgh Section has been appointed to serve for a five-year term.

The members of the Committee and their terms from 1 July 1949 are listed below:

Lloyd A. Knowler, Chairman	4 years
Paul S. Olmstead	1 year
Martin A. Brumbaugh	2 years
Charles J. Hudson	3 years
Edwin G. Olds	5 years

The Executive Committee has expressed to Dr. Olmstead and Dr. Shewhart the sincere appreciation of the Society for their services in the first work of the Examining Committee.

SHEWHART MEDAL COMMITTEE

At its meeting in Boston on May 6 and 7, the Executive Committee reviewed the recommendations of the Shewhart Medal Committee and voted to increase the membership of the Committee from 6 members to 9 members.

The three new members appointed by the President to serve on the Committee are:

Warren R. Purcell, Boston Section
Charles E. Stines, Dayton Section
Paul A. Robert, Southern Tier Section.

Each of the newly appointed members will serve for a three-year term.

The following members of the Shewhart Medal Committee will continue to serve for the terms listed below:

Philip L. Alger, Chairman	1 year
Charles A. Bicking	1 year
Ernest L. Fay	1 year
Irwin S. Hoffer	2 years
G. Ruppert Gause	2 years
Andrew I. Peterson	2 years

All committee terms begin on July 1, 1949.

Early in September, each Section Chairman will receive a letter from the Shewhart Medal Committee requesting nominations for the 1949 Medallist.

NOTICE

Send in your nomination for the first Brumbaugh Award before November 1, 1949. See p. 30, May IQC, for details.

POSITIONS WANTED

COLLEGE GRADUATE, majored in Industrial Engineering with a Quality Control specialty. Wants position preferably in quality control, or else time study or plant layout. Capable, industrious, and ambitious. Member of ASQC. Available August 1, 1949. Write to: Mr. M. B. Rothman, 25 Hunter Avenue, New Rochelle, N. Y.

ENGINEER (mechanical research). Registered. Senior member ASQC. Presently employed. Unusual ability in planning and analyzing research. Thorough experience in applying statistical methods to research, inspection and process control. Competent to develop, apply and supervise process control, inspection and to teach staff. Many years of successful supervisory experience. Seeks position allowing greater scope for statistical abilities and interests. Excellently fitted for technical assistant or advisor to research, manufacturing or inspection executive. Reply to 6A1, American Society for Quality Control, 22 East 40th Street, New York 16, N. Y.

COLUMBIA GRADUATE; B. S. in Chemical Engineering; M. S. in Industrial Engineering, (majored in engineering statistics and quality control). Desires quality control position in chemical industry. Member ASQC. Write to 6A2, American Society for Quality Control, 22 East 40th Street, New York 16, N. Y.

CONSULTING SERVICES

Responsibility of the American Society for Quality Control, Inc., for Consulting Services advertising is limited to certification that advertisers hold the grade of membership in the Society stated in their advertisements. Qualification requirements for the several grades of membership are set forth in the Constitution of the Society.

Management Controls

FOUNDED IN 1945

References and Literature on Request

Senior Partner: 699 ROSE AVE.
W. E. JONES DES PLAINES, ILL.
Fellow, ASQC DES PLAINES 1493

RALPH E. WAREHAM
Fellow, ASQC
CONSULTANT ON QUALITY CONTROL
122 ORCHARD RIDGE TELEPHONE
CHAPPAQUA, N. Y. CHAPPAQUA 715

Werner Textile Consultants
Integrated Technical, Statistical Quality and Waste Controls
H. L. WERNER **60 East 42nd St.**
Sr. Member ASQC **New York 17**

Buy From Our Advertisers

ADVANCE NOTICE

(Watch for Program Details in the September Issue)

Fourth Midwest Quality Control Conference

St. Louis, Missouri

THURSDAY AND FRIDAY, NOVEMBER 10-11, 1949

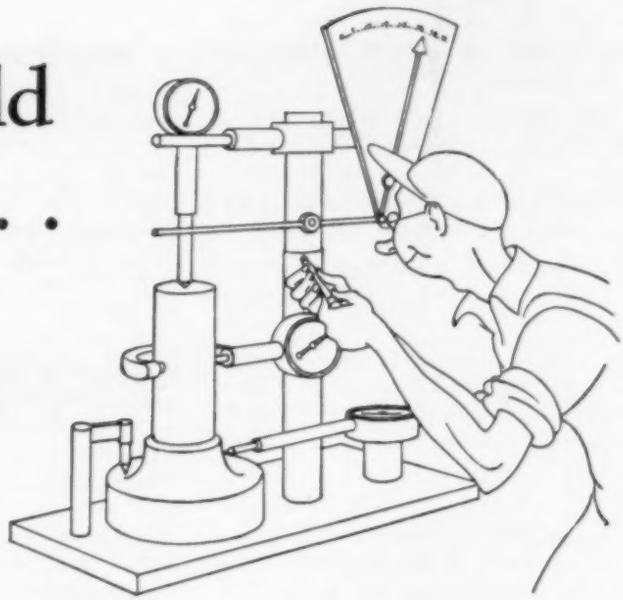
Featuring

1. A two-day training course in basic SQC
2. A unique and flexible clinic program
3. Gage and Quality Control exhibits
4. Abstracts of program papers

"GREATER QUANTITY — BETTER QUALITY — LOWER COSTS"

Sure you can build your own gage . . .

BUT *can you afford it?*



You can't tell the true cost of a gage until you put it on the job. We see it all the time . . . thousands of dollars wasted in machine time, man-hours, and scrap because inspection gages don't live up to expectations. Old style gages, improperly designed special gages, or inspection tools of the wrong type may be imposing a heavy tax on your profits.

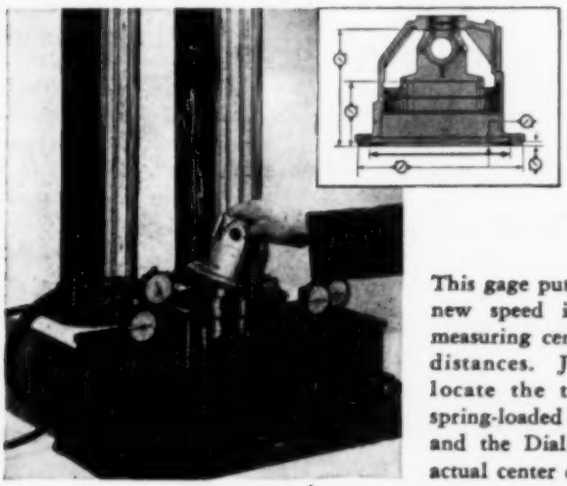
Why put up with this when you can obtain production-proved special gages built by *Gaging Specialists!* Federal Gages have money-saving features:

- **precision** that puts the finger on faulty work
- **speed** that cuts down inspection time
- **design** that positively checks the exact dimension in question
- **convenience** that eliminates inspector fatigue
- **visibility** that makes for easier, surer gaging
- **size readings** that are essential to quality control

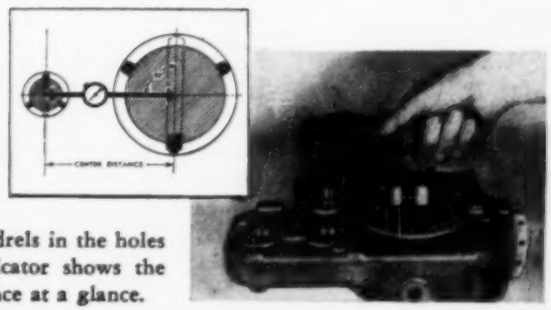
The design of each Federal Gage—manual, semi-automatic, or automatic—is based on years of experience in engineering and manufacturing gages for almost every conceivable dimension.

Whether mechanical, air, or electronic, a Federal Gage is built to deliver real profits in speed and economy. Let us recommend the right Gage for your needs — our nearest representative will be glad to discuss the details of your problem. Or send blueprints and specifications to Federal Products Corporation, 1114G Eddy Street, Providence 1, R. I.

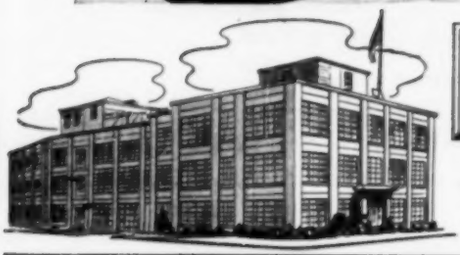
Here's how FEDERAL solved a couple of inspection problems



◀ A leading vacuum cleaner manufacturer inspects 8 dimensions of motor housings on this combination Air and Dial Indicator Gage. In one time-saving operation, four depths and four diameters are checked simply by positioning the workpiece and taking the dimensional readings.



This gage puts ▶ new speed into measuring center distances. Just locate the two spring-loaded mandrels in the holes and the Dial Indicator shows the actual center distance at a glance.



FEDERAL

PRECISION MEASURING INSTRUMENTS

DIAL INDICATORS • INDICATING GAGES • SPECIAL GAGES • ELECTRONIC AND AUTOMATIC SORTING GAGES • AIR GAGES